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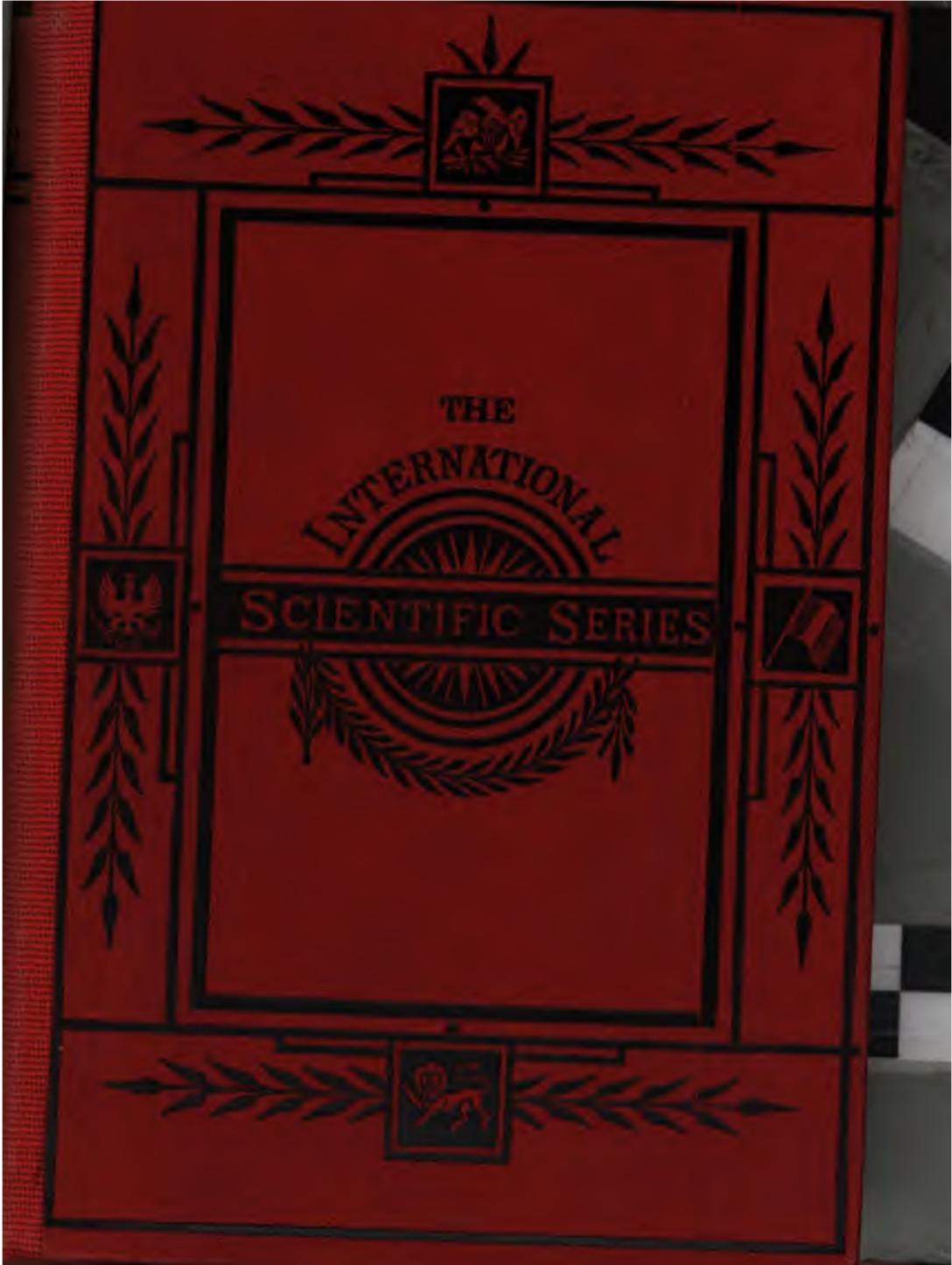
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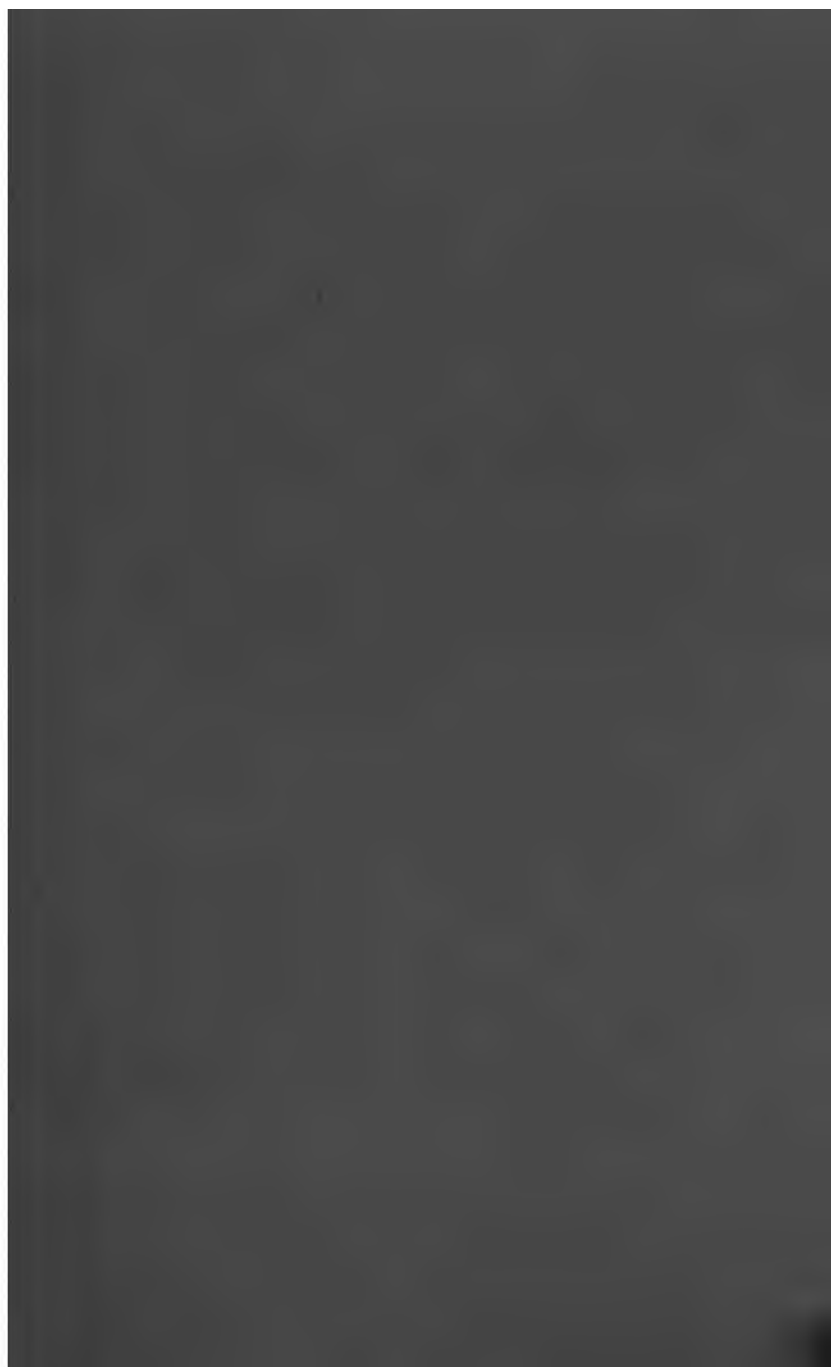


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FIG. 1.—BOSEKOP (LAPLAND) AURORA WITH ARC AND DRAPEY.

MARE ISLAND, CALIF.

THE INTERNATIONAL SCIENTIFIC SERIES

THE
AURORA BOREALIS

BY

ALFRED ANGOT

HONORARY METEOROLOGIST TO THE CENTRAL
METEOROLOGICAL OFFICE OF FRANCE

WITH EIGHTEEN ILLUSTRATIONS

NEW YORK
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Authorized Edition.

P R E F A C E.

THE first work, devoted entirely to the study of Polar Auroras, was written in France; it is entitled '*Traité Physique et Historique de l'Aurore Boréale*,' and was published in 1733 by De Mairan, in the '*Mémoires*' of the '*Académie des Sciences*.' We must allow a century to elapse before we find anything to be compared with it in importance and volume, when the work '*Aurores Boréales*' appeared in the collection of the voyages of the Northern Scientific Commission on the corvette '*Recherche*.' This volume, accompanied by magnificent plates—of which we shall reproduce the most interesting—contains records of observations of the aurora borealis taken in Lapland during the winter of 1838-39 by Bravais, Lottin, Lillihoeok, and Siljestroem. Bravais added general remarks on this phenomenon, and discussed the principal observations collected at that date, and the various hypotheses put forward to account for them.

Since then no general work on the subject has appeared in this country. The student was obliged to consult original papers published in all languages, or foreign treatises, among which we will mention only one as the most complete, that of Hermann Fritz of Zurich, 'Das Polarlicht' (Leipzig, 1881).

I have tried to meet this want by writing in the journal 'La Lumière Electrique' (vol. vii., last half of 1882) a series of ten articles on the Polar Aurora, accompanied by numerous plates, which reproduce from the original documents the principal appearances of the polar aurora. These articles, revised according to the most recent discoveries, have served as the basis of the present work.

It would have been easy to increase considerably the size of this volume by citing a greater number of the results of observations. I thought, however, that it was better to choose for each class of phenomena two or three of the most conclusive examples, borrowed from those observers who are most worthy of confidence. I have not tried to publish all the observations collected at all times and in all countries on Polar Auroras. I have rather sought to give a sketch of the actual state of our knowledge of this question, noting the results which may be considered as defi-

nitely acquired, and also the points on which further research seems unnecessary.

I have indicated in the course of the work the most important books and papers on each branch of the subject; but here, also, some limit was necessary. For these works must now be reckoned by hundreds, some containing merely observations of the aurora, others theories about it. A complete bibliography of the subject would alone fill a large volume.

The figures in the text are reproduced directly, and as exactly as possible, from the original documents, and their source is always indicated. They are taken partly from the fine atlas of Bravais, which contains the most beautiful engravings of the aurora borealis which have yet been published. I have been able to add drawings which are less known, and some never before published. In particular, my thanks are due to M. de la Monneraye, a lieutenant in the navy, who kindly placed at my disposition a remarkable series of drawings which he executed himself in the course of a sojourn in the seas near Newfoundland.

In the Appendix will be found a list of all the appearances of the aurora borealis observed from 1700 to 1890 in Europe below the 55th parallel of latitude. Above this limit auroras are so frequent that at certain epochs they may be seen almost every day. In

drawing up this catalogue I have chiefly followed that of Fritz, which is a summary of all previous catalogues. I have only had to add the observations of the last twenty years. Such catalogues are indispensable for almost all the studies which relate to Polar Auroras; and since Mairan's, in the middle of the last century, none had been published in France. The service which this catalogue may render will, I hope, excuse its length and aridity.

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THE POLAR AURORA.



CHAPTER I.

HISTORY.

POLAR AURORAS, which are subdivided into aurora borealis and aurora australis, according to the hemisphere in which they occur, are assuredly the finest of the optical phenomena of nature, but are, even at the present day, one of the least understood. While by their sudden appearance, their superb colouring, their rapid movement, their infinitely varied form, the northern lights have from all time excited the attention of the multitude, their mysterious nature and the relations which seem to connect them with terrestrial magnetism, and even with certain cosmic phenomena, such as the spots in the sun, make them the subject of the study of meteorologists and physicists.

The aurora borealis was already known to the Greeks and Romans, although it is a rare phenomenon in districts so far south as the shores of the

Mediterranean. Aristotle touches on them briefly in his 'Meteorology.'¹ He says that they sometimes present the appearance of the smoke of the straw which is burnt in the country, and his observation is exact. Other forms of the aurora borealis are designated by him under the name of *brands* (δαλοὶ) and goats (αἴγες): the author enters into no explanation, but this last name may plausibly be referred to certain luminous rays, of which we shall speak later, which show rapid alternative movements in the direction of their length, and thus appear to leap. Further on, among the phenomena which may be observed on calm nights, Aristotle enumerates *gulfs* and *abysses* (χάσματα, βόθυνοι) and sanguine colours. The first two expressions doubtless refer to what is now known as the obscure segment, the dark part of the heaven which is seen in the form of an arc, below the aurora. This identification appears the more probable that Aristotle adds: 'The gulfs seem to have a certain depth because of the contrast which the light makes with the black and blue colour of the sky. Often even, when they contract, brands or torches issue from them (δαλοὶ in Greek); the gulf then seems to converge.' These few lines appear to be absolutely incomprehensible in certain French translations; as rendered above they correspond with sufficient accuracy to certain aspects of the aurora borealis.

¹ Lib. i. 4 and 5.

Cicero merely mentions twice the aurora, which he indicates by the term *torches*.¹

Pliny, the naturalist, is much more explicit,² and he cites the precise epochs at which the phenomenon was observed.

‘Beams (*trabes*) are seen to shine in the heaven, which are called *δοκοί* in Greek, as it happened at the time when the Lacedæmonians, vanquished at sea, lost the dominion over Greece. In the sky appears a gulf which is called *chasma* (the Greek word translated directly into Latin). And, besides, there is seen in the heaven (and nothing is more terrible for trembling mortals) blood-coloured flames which afterwards fall upon the earth, as it happened in the third year of the hundred and seventh Olympiad, when King Philip ruled over Greece. Under the consulate of C. Cæcilius and Cn. Papirius, and on many other occasions, a light was seen in heaven which made the night almost as light as day. It is said that at the time of the wars of the Cimbri, and also often before and since, the clashing of arms and the sound of trumpets were heard in the sky. But in the third consulate of Marius the dwellers in Ameria and Tuderta saw in the heavens two armies rushing one against the other from the east and from the west; that of the west was defeated. The heaven

¹ *De Natura Deorum*, ii. 5: ‘tum facibus visis cælestibus;’ *Catilin.* III. viii.: ‘visas nocturno tempore ab occidente faces ardoremque cæli.’

² *Hist. Nat.* ii. 26, 27, 33, and 57.

itself caught fire : this is no extraordinary thing, and it has often been seen when the clouds are exposed to great heat.'

In this quotation from Pliny we find for the first time the trace of that popular superstition which obtained almost down to our own day, and which attributed the great auroras to armies combating in the sky.

Seneca¹ gives a few more details, curiously exact, showing that observers in classic times were often more accurate than those of several centuries later. Speaking of the different sorts of heavenly fires, Seneca describes a certain number of appearances which are clearly the aurora borealis ; but instead of using Latin words to describe them he borrows the Greek terms of Aristotle, which we gave above. Here is the passage from Seneca :—

'Sometimes flames are seen in the sky, either stationary or full of movement. Several kinds are known : the abysses, when beneath a luminous crown the heavenly fire is wanting, forming as it were the circular entrance to a cavern ; the tuns (*pithitæ*), when a great rounded flame in the form of a barrel is seen to move from place to place, or to burn immovable the gulfs (*chasmata*), when the heaven seems to open and to vomit flames which before were hidden in its depths. These fires present the most varied colours : some are a vivid red ; others resemble a faint

¹ *Naturales Quaestiones*, i. 14, 15.

and dying flame ; some are white ; others scintillate ; others finally are of an even yellow, and emit neither rays nor projections. Among these phenomena should be ranged those appearances as of the heavens on fire so often reported by historians ; sometimes these fires are high enough to shine among the stars ; at others, so low that they might be taken for the reflection of a distant burning homestead or city. This is what happened under Tiberius, when the cohorts hurried to the succour of the colony of Ostia, believing it to be on fire. During the greater part of the night the heaven appeared to be illuminated by a faint light resembling a thick smoke.'

The mistake mentioned by Seneca is so natural that it has often occurred since. At Copenhagen, in 1709, during a large and brilliant aurora, several battalions turned out under arms and beating drums.

The Greek and Roman authors often confounded certain faint auroras with comets, and it is probable that the catalogues of early appearances of comets contain many errors of this description. The mistake is manifest when it is stated in the description that the comet appeared in the north and only lasted a few hours, or even less ; in this case it was simply a ray of the aurora borealis. Such, for instance, was the supposed comet of October 11, 1527, in France, in Germany, and almost the whole of Europe : it was of immense length ; its summit was like an arm, bent at the elbow ; it was only visible towards the north,

and lasted but an hour and a quarter. It was of an orange-red colour, 'and joined to it were dark rays in the form of tails, lances, bloody swords, figures of men, and heads cut off, bristling with hair and beards.' From all these details it is easy to recognise in the phenomenon an aurora borealis.

Among early records of the aurora we will cite yet another, mentioned by Gregory of Tours. He says he saw the appearance himself, and his description is interesting, both from its simplicity and accuracy, and because the form now known as the 'boreal crown' is clearly indicated for the first time: 'Two nights in succession we saw signs in the heavens, that is to say rays of light which rose in the north, as often happens. A great light took possession of a part of the sky and seemed to overflow it. . . . There was in the middle of the heaven a cloud of light, towards which all the rays converged, in the form of a tent of which the sides, much wider at the foot, ascended, narrowing to the summit, where they united, often in the shape of a hood.'¹

Gregory of Tours in several other places mentions the aurora borealis, and his descriptions are always equally simple: he considers the aurora as a curious manifestation, but attaches to it no idea of the supernatural. Some centuries later astrology had so troubled the minds of men that the aurora borealis had become a source of terror: bloody lances, heads

¹ *Historia Francorum*, viii. 17.

separated from the trunk, armies in conflict, were clearly distinguished. At the sight of them people fainted (according to Cornelius Gemma), others went mad. Pilgrimages were organised to avert the wrath of Heaven, manifested by these terrible signs. Thus, according to the Journal of Henri III., in the month of September 1583 eight or nine hundred persons of all ages and both sexes, with their lords, came to Paris in procession, dressed like penitents or pilgrims, from the villages of Deux-Gémeaux and Ussy-en-Brie, near La Ferté-Gaucher, 'to say their prayers and make their offerings in the great church at Paris; and they said that they were moved to this penitential journey because of signs seen in heaven and fires in the air, even towards the quarter of the Ardennes, whence had come the first such penitents, to the number of ten or twelve thousand, to Our Lady of Rheims and to Liesse.' The chronicler adds that this pilgrimage was followed a few days afterwards by five others, and for the same cause.

These superstitious terrors lasted at least till the end of the seventeenth century. La Mothe le Vayer, who was tutor to the Duke of Orleans, brother of Louis XIV., and afterwards to Louis XIV. himself, and who entered the Academy in 1639, alludes to these popular beliefs in his 78th letter, entitled 'De la Crédulité:' 'I will take my second example (of credulity) from the writings of Baptiste le Grain, for whom I have a great esteem: he says in his sixth

book that he observed in Paris in 1615, about eight o'clock in the evening of the 26th of October, men of fire in heaven, who fought with lances, and who by this terrifying spectacle foretold the fury of the wars which followed. Yet I was with him in the same town, and I protest, having studied attentively until eleven at night the phenomenon of which he speaks, that I saw nothing similar to his description, but only an appearance which is sufficiently common, in the form of pavilions in the sky flaming up and fading out again, as is usual with such meteors. A number of persons now living will testify to what I say.'

It was towards this epoch that, as a result of the observations of Gassendi, and later of those of Cassini, of Roemer, &c., the aurora ceased to be regarded, at any rate by the educated classes, as a supernatural phenomenon, presaging horrible calamities. Yet even at the present day, in rural districts, simple folk might be prone to attribute a supernatural origin or significance to the aurora if its appearance should chance to coincide with striking events or great disasters. Perhaps some vestiges of this ancient superstition might have been found at the time of the remarkable aurora borealis which was observed throughout France during the nights of October 24 and 25, 1870.

The Norsemen believed that the aurora represented the Valkyries riding through the air on their sombre

horses. This belief, indicated by Tacitus in his description of Germany, is given more explicitly in several passages of the Edda. But since this phenomenon is of common occurrence in the north, familiarity early deprived it of all its terrors. About the year 1250, less than a century after the composition of the Edda, a Norwegian, who probably lived near the town of Nansos (to the north of Trondhiem), wrote a work, at once philosophical and political, entitled 'The King's Mirror' (*Konungs Skuggsjà*), which is remarkable on more than one count: in it the aurora is thus described: ¹—

'The nature and constitution of the northern lights are such that the darker the night the brighter they shine: they are never seen by day, but only at night, especially in profound obscurity, and rarely by moonlight. They appear like a great flame seen from a distance, as though that of a vast fire. From the smoke of it pointed shafts of unequal and very variable size seem to dart upwards into the air, so that now the one and now the other is the higher, and they seem to quiver like flames. When these rays are at their highest and brightest they give so much light that one can find one's way about quite easily out of doors, and even hunt if this is desired. In houses with windows it is light enough within for men to see each other's faces. This light is so variable

¹ Sophus Tromholt, *Zur Geschichte des Nordlichts* (*Meteorologische Zeitschrift*, vol. ii. 1885, p. 24).

that it sometimes becomes obscured, as though it were covered by thick smoke or cloud; and soon it seems to be stifled by this smoke and near extinct. But as soon as the cloud begins to dissipate and grow less thick, the light increases and glows again, and sometimes great sparks seem to fly from it, as from a red-hot iron taken from the forge. As the night advances and dawn approaches, this light begins to pale, and it fades altogether when day breaks. Certain people maintain that this light is a reflection of the fire which surrounds the seas of the north and of the south; others say that it is the reflection of the sun when it is below the horizon; for my part I think that it is produced by the ice which radiates at night the light which it has absorbed by day.'

Note, by the way, this first attempt at an explanation of the polar auroras. Doubtless it is not very convincing and would not be considered satisfactory at the present day; but we must not smile at it, since it is nearly the same as that which many centuries later was suggested both by Descartes and Sir John Franklin.

We may add, in concluding this historical sketch, that Gassendi, in 1621, first used the term *aurora borealis*. In the seventeenth century and even in a part of the eighteenth, as this appearance was not known to exist in the southern hemisphere, the light was called *borealis* when it appeared in the northern quarter of the sky, and *australis* when it appeared to

the south, but always to an observer in the northern hemisphere.

Although polar auroras were seen in Chili as early as 1640, the first certain observations taken in the southern hemisphere and known in Europe were those of Antonio de Ulloa. During the voyage round Cape Horn in 1745 he more than once had occasion to observe a polar aurora, and he maintains that they must be as frequent in the southern hemisphere as in our own. Since then the name of aurora borealis has been restricted to those which are seen in the northern hemisphere, round the north pole, and that of aurora australis to those which are seen round the south pole. The name *polar aurora*, therefore, is to be preferred as being more general.

In England and the United States the name proposed by Gassendi has been adopted in scientific phraseology to designate this phenomenon. The sailors of the north of England call them *northern lights*, or *streamers*. In Germany and Scandinavian countries the ancient name of northern light which we find in 'The King's Mirror' has been retained, *Nordlicht* in German, *Nordljus* in Swedish, *Nordlys* in Danish.

CHAPTER II.

FORMS OF THE POLAR AURORA.

THE polar aurora offers the most varied and complex forms, as the reader can judge from the illustrations in this work, which reproduce as faithfully as possible the original drawings made by competent observers in presence of the phenomenon. The source of each engraving is always indicated, thus facilitating the reference to the original descriptions.

We shall divide the polar auroras into two great classes: those which are apparently motionless, or at least of which the various parts retain for a certain time their relative position and intensity; and those which, on the other hand, present rapid and incessant variations in shape and brilliancy. In the first class we distinguish three principal forms:

1. Faint lights without very defined form.
2. More distinct lights, grouped in patches which often present the appearance of clouds.
3. Clearly defined arcs, formed of a homogeneous luminous mass touching the horizon at either extremity.

In the second class, that of auroras presenting

rapid movements, three principal subdivisions are also observed.

4. Non-homogeneous arcs, of which the brilliancy is not uniform, nor the border regular; from these arcs rays shoot upward intermittently.

5. Rays isolated from each other, at a greater or less distance: they seem to converge upon a fixed point in the sky, and sometimes form round this point a sort of glory or crown.

6. Non-homogeneous bands, formed of rays pressed close together which have not all the same degree of brilliancy. These bands of light have a height proportioned to their width: sometimes they seem to fold over on themselves, and then they become the draped auroras, which are the most beautiful manifestations of the polar aurora.

These different forms, which we separate for purposes of description, and which, moreover, are most often seen singly, may yet exist simultaneously or successively in the same aurora, as we shall see in the examples given in the course of this study.

1. *Faint lights without very definite form.*—There is not very much to say about these faint and ill-defined lights, which constitute the first type of polar auroras. They are of the most varied dimensions, sometimes very small, sometimes occupying almost the whole heaven: their brilliancy is at times not greater than that of the Milky Way; they then form, as it were, a white veil over the sky. At other times

they only feebly light up the horizon, and it is probable that under this form they often pass unobserved, either because they are masked by a stronger light, such as that of the moon, or by that reflected in the sky by the illumination of great towns, or because they are taken for the last rays of the sunset or the first of the dawn. At times, again, when their light is somewhat stronger, they appear on the horizon as the reflection of a distant fire, illuminating the edges of the dark clouds which interpose between them and the spectator. Finally—but this is rare—the focus of these lights may be, not on the horizon, but at some distance above it, though the elevation is never many degrees.

Faint auroras of this class are often called *Licht-process* by German authors: they appear to be of frequent occurrence in Europe, but they escape the attention of all but careful observers whose attention is specially directed to this phenomenon.

It is perhaps with this species of polar aurora that we should connect the sort of phosphorescence which on certain nights illumines the whole atmosphere. Such a light was observed at Göttingen during the night of November 13 and 14, 1866, when, without apparent cause, the sky remained as light as it is usually in the shortest summer nights.

2. *Lights in the form of clouds. Auroral bands and patches.*—The greater number of auroras which have been observed in France belong to this class.

They are vague lights without very defined outline, of which the colour is generally a yellowish or greenish white, more rarely a beautiful rose colour. They affect, for instance, the form of clouds of smoke, like the aurora which was observed and drawn in February 1874, by the expedition under Payer and Weyprecht on board the 'Tegetthof' at Franz Josef Land. Still more often they resemble those light clouds, like feathers or tufts of carded cotton, known to meteorologists as cirrus.

This species of aurora is often seen alone, or it may mark the beginning and the end of more complete auroras.

The resemblance between some of these auroras and cirrus clouds may be so close that it becomes sometimes impossible to distinguish whether we are really gazing on a manifestation of the northern lights or on true clouds lit up by some reflected light. We quote textually, by way of instance, from the notes taken by Bravais at Bossekop¹ on October 1, 1838, during an observation of an aurora borealis.

'11.45. To the north north-west a yellowish light in the form of a flattened arc. Is it a cirro-stratus or an arc ?

'11.57. The flattened arc seen at 11.45 is decidedly a cirro-stratus.

¹ Voyages of the Scientific Commission of the North in Scandinavia, Lapland, Spitzbergen, and the Faroe Islands during the years 1838, 1839, and 1840 on the *Recherche*.

‘12.15. The cirro-stratus in the north north-west still simulates the arc of an aurora.

‘1.45. Its form is now clearly defined: the series of cirrus which compose it are nearly parallel, converging like the rays of an aurora.

‘2.0. The great cirro-stratus, passing from the north-west to the south-west, has sent towards the zenith a good number of scattered cirri: these seem (if I rightly distinguish these cirrus clouds from the lights of the aurora) to obey the force which directs the rays of the aurora.’

The analogy of these forms of the aurora with certain clouds is, then, so great that a skilled observer like Bravais hesitates to pronounce upon them, and, after declaring at one moment that they are really clouds that he sees, ends by questioning whether he clearly distinguishes these clouds from the aurora itself.

The coexistence of these cirrus clouds with the discs or bands of the aurora has, moreover, been frequently observed. It is well known that the cirrus is formed of little needles of ice, which, refracting the light of the sun or moon, produce the optical phenomena known as halos, parhelia, &c. Now on November 2, 1838, one of Bravais' companions, Lilliehøæck, observed around the moon, during an aurora borealis, the ordinary halo of twenty-two degrees of radius. ‘There is,’ he says, ‘an intimate relation between the light of the halo and that of the aurora,

for where a ray of the latter cuts the halo the ray becomes wider and its light appears more condensed.' We shall see later the important bearing of observations of this nature on the theory of polar auroras.

It would be easy to multiply similar quotations, and to show that, not only is it possible to confound the aurora with cirrus, but that the two phenomena are frequently mingled. In the twilight of the dawn cloudy bands have been seen to take the place of the bands of the aurora. At other times arched clouds exist in the sky before nightfall, and it is the aurora, on the contrary, which seems to take their place. The two phenomena may succeed each other or coexist, and it then seems probable that the auroral light allied during the night with the cirrus persists with it in the daytime, although it is no longer possible to distinguish its proper light.

The auroral patches and bands often exhibit curious variations in brilliancy, and these have been named by Bravais palpitating lights. We will borrow as an example the following details from Bravais' observation of October 22, 1838: 'These are patches of a faint yellow colour, into the centre of which is injected from time to time a brilliant light of a more vivid colour, which lasts but an instant. The patches seem subject to alternate expansion and contraction, which may be compared to the movement of medusæ swimming in the sea. It is a curious fact that the different patches of light which occupy different parts of the

sky undergo simultaneously this alternative movement. To the dilatation is added at the same time an increase in the intensity of the light. Independently of this alternative movement the patches undergo a change in form and intensity which is much slower, and does not appear to be periodic. The peristaltic movement generally consists of one or two sharp beats, lasting half a second or so, after which there is a pause of a few seconds, and the beats begin again. Some of the patches are doubled in extent and in brilliancy relatively to their contracted state.'

The causes to which this palpitation of the light is due may persist for several days. Instead of all the auroral patches of light obeying the same alternative movement, these patches may form part of two series, of which the one palpitates, while the other is completely free from movement. The spots of light in the two series may be so similar, and so much mingled together, that the eye of the observer cannot, during the period of repose, distinguish them the one from the other; they may perhaps, however, belong to two different planes.

Sometimes, finally, the obscure phase amounts to total extinction, and as the patches, on reappearing, have not always retained their original position, they resemble 'the clouds of smoke poured forth by a distant locomotive' (Bravais).

A curious phenomenon, mentioned by Hildebrand-

son,¹ director of the observatory at Upsala, may be connected with this second type of auroras. On July 25, 1877, on the south of Lake Wetter, two observers remarked, between two storms which succeeded each other at an interval of three hours, less than two yards above the surface of an arm of the lake, a luminous floating mass of a red colour, transparent and clearly defined, with undulating outlines. It was unmistakably relieved against the other shore of the lake, which was wooded and at a distance of 750 yards. The length of the luminous mass might be about 200 yards. Somewhat later a similar light was seen three times: it lasted on each occasion about two seconds. Hildebrandson considers this phenomenon as a transition between the polar aurora and the electric discharge of a storm.

Luminous effects, which are probably also forms of the aurora borealis, have on other occasions been seen very near the ground. The following case is thus described by Arago:²—

‘Major Sabine and Captain J. Ross were returning in the autumn from their first Arctic expedition; they were still in the Greenland seas, during one of the dark nights of those regions, when they were summoned to the bridge by the officer of the watch, who had just seen something very strange. This was,

¹ *Zeitschrift der österreichischen Gesellschaft für Meteorologie*, vol. xiii. 1878, p. 124.

² Arago, *Œuvres complètes*, vol. iv. p. 146.

ahead of the vessel and precisely on their course, a stationary light, which rose to a great height from the surface of the sea, while in all other directions the sky and horizon appeared black as pitch. There was no known danger in those regions, and the direction of the vessel was therefore not changed. When the vessel entered the circle of light the whole crew was silent, attentive, on the alert. The highest parts of the masts and sails could then be seen and all the rigging. The meteor appeared to extend for about four hundred yards. When the stern of the vessel left it it was again in darkness; there was no gradual decline in the intensity of the light. The luminous region could be seen from the stern of the ship for a long time.'

3. *Homogeneous arcs*.—In certain regions, and probably also at certain epochs, the polar aurora manifests itself simply as a very regular arc of a circle, with well-defined outlines and uniformly luminous in all its parts, so that it presents an absolutely homogeneous texture. It is under this form that the aurora borealis most often presented itself to Professor Nordenskiöld in 1878-79 during the celebrated wintering of the 'Vega' on the northern coast of Siberia, almost at the entrance to Behring Straits.¹ In this station the summit of the arc

¹ *Om norrskenen under 'Vegas' oefvervintring vid Berings Sund, 1878-79*, af A. E. Nordenskiöld. A French translation of this work has been published by M. de Saporta in the *Annales de Chimie et de Physique* 1884, vol. i.

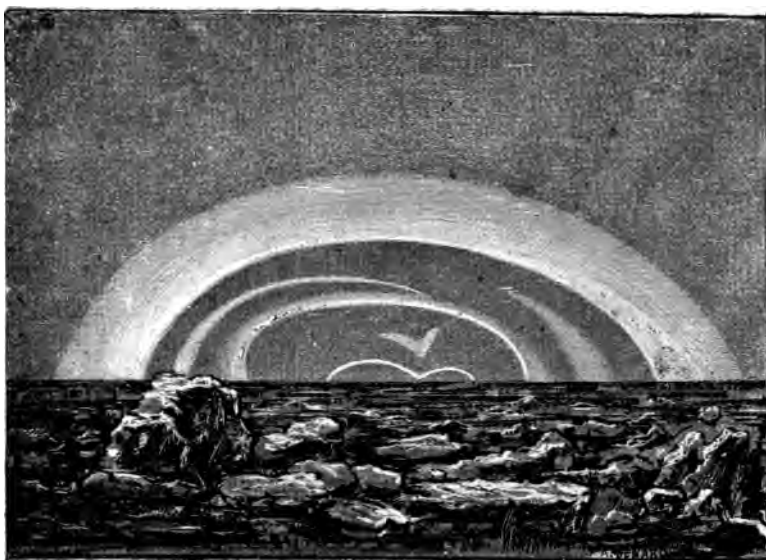


FIG. 2.—WINTERING OF THE 'VEGA.' ELLIPTICAL ARCS.

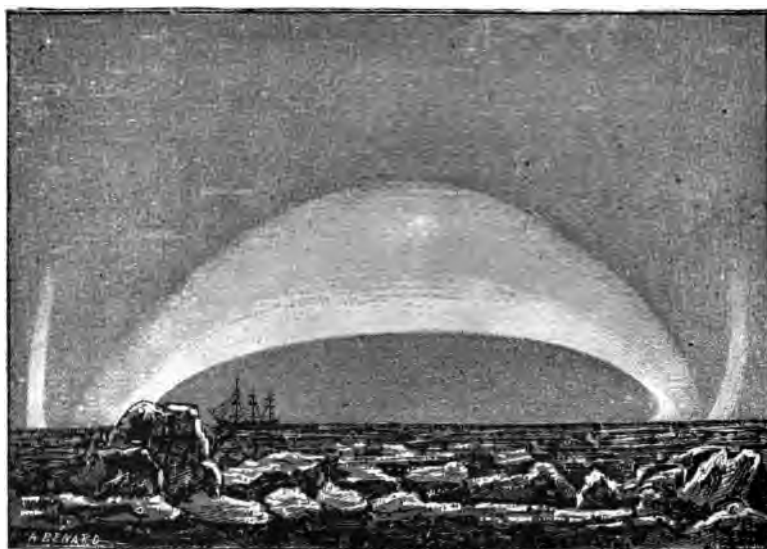


FIG. 3.—WINTERING OF THE 'VEGA.' ELLIPTICAL ARCS.

rarely exceeded a height of thirty degrees above the horizon, so that its centre remained well below the horizon.

These arcs are generally completely motionless and remarkably permanent: they often retain their position for hours and even for several days. As a rule their summit is nearly in the magnetic meridian or the direction indicated by the needle of a compass. We shall recur to this coincidence, which is of great importance.

It sometimes happens that these arcs, instead of being circular, are distinctly elliptical (figs. 2 and 3). The two curves which constitute its upper and under edges may not be at all points at the same distance from each other; they may be, for instance, two ellipses having the same centre, and of which the axes are unequal; in this case the width of the arc is not the same at all points (fig. 3).

Sometimes, instead of a single circular arc, there are two which are perfectly concentric; they may even coexist to the number of three or four (fig. 4). A more remarkable and much more rare case has also been observed by Nordenskiöld, that in which the aurora presents itself in the form of two arcs of which the centres are far apart, so that the arcs cut each other (fig. 5), or even only touch at one foot. But in this case the aurora no longer retains the fixity which characterises the single homogeneous arc: these anomalous forms only last a short time, and

are a transition towards the variable auroras which compose the second class.

4. *Non-homogeneous arcs, or arcs with rays.*—The arcs with rays, which constitute the first variety of auroras of the second class, may be developed by insensible degrees from the homogeneous arcs of the third type which we have just described. Instead of being formed of a fixed and even light, they appear to be composed of a great number of fibres or rays of which the direction is perpendicular to the length of the arc. As a rule these rays are more luminous portions detached, not from the dark ground of the sky, but from a paler nebulous arc. If, on the contrary, the rays are projected on a very dark ground, and if at the same time they are wider than the spaces which separate them, the spaces take in their turn the appearance of rays or black stripes (see fig. 8): these black stripes are not a distinct phenomenon and have no real existence; it is only the dark background of sky seen through the narrow interval separating two luminous rays which are very near to each other.

The transverse rays which compose the arc appear to be parallel to each other if their length is not great; but if they are sufficiently developed it becomes evident that they really all converge towards a fixed point in the heaven. This point is usually close to the magnetic zenith, that is to say the place to which a suspended and magnetised needle points. It is



FIG. 4. — WINTERING OF THE 'VEGA.' MULTIPLE ARCS.

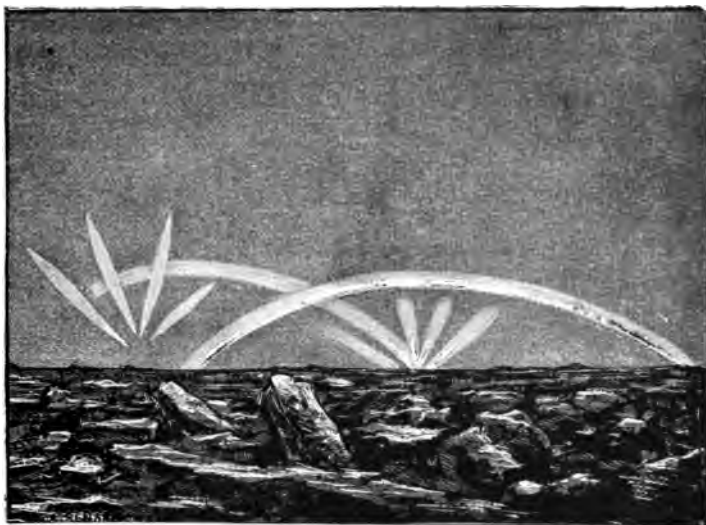


FIG. 5.—WINTERING OF THE 'VEGA.' MULTIPLE ARCS WITH
DIFFERENT CENTRES.

enough for the moment to indicate this fact, to which we shall return when we come to speak of the relation of the aurora borealis to terrestrial magnetism.

The transverse stripes which compose these arcs are generally clearly defined at the lower end, following a more or less regular curve which limits the arc. The upper end, on the contrary, is commonly less distinct; sometimes the arc is shaded off above and seems to fade into the sky (fig. 6).

The striped arcs have a less regular form than the nebulous kind, of homogeneous structure, belonging to our third group. Their lower edge often presents indentations or waves which the others have not. Yet the mean curve is generally about the same in both cases, and so with their colour, which is usually a yellowish white, and rarely shows red or violet tints.

These arcs generally vary incessantly, as may be seen in fig. 6, which represents five successive stages in an aurora observed at Bossekop (Lapland) by Bravais and Lottin on January 12, 1839. The striped arcs change into more or less homogeneous arcs, or *vice versa*. Sometimes they seem to melt away at one end; sometimes they vanish completely to reappear the next moment. At the same time they display the most varied movements; for instance, they transport themselves from the north to the south, or the south to the north. At other times, again, the height of the arc remaining constant, its feet, that is to say the points at which it touches the horizon, move in direc-

tions opposite to each other, as if the whole arc turned round a vertical line from east to west, or from west to east. The rapidity of these movements is very variable: at Bossekop, Bravais and Lottin frequently saw arcs rise as much as five degrees a minute; once an arc changed its place with a rapidity corresponding to seventeen degrees a minute. It will be understood that these movements hamper the observations considerably, and sometimes render it impossible to secure accurate measures of the form and the height of these arcs.

Multiple striped arcs are not uncommon, at least in certain districts. During the 201 days which the French Commission spent at Bossekop, and out of 151 on which there were auroras, on one occasion as many as nine arcs were seen at one time; twice, seven were seen, twice, six arcs, once five, and three times four; that is, there were nine nights out of 151 when the number of arcs seen at one time was four or more. Triple or double arcs were extremely common.

Certain rays of the arc have sometimes a great length: this elongation is nearly always from the upper border; once only, as an exception, the French Commission saw at Bossekop rays starting from the lower border of the arc and pointing to the horizon. This form of arc, from which long rays spring towards the zenith, is one of the finest manifested by the polar aurora in France. We give an example in fig. 7, which represents the aurora bore-

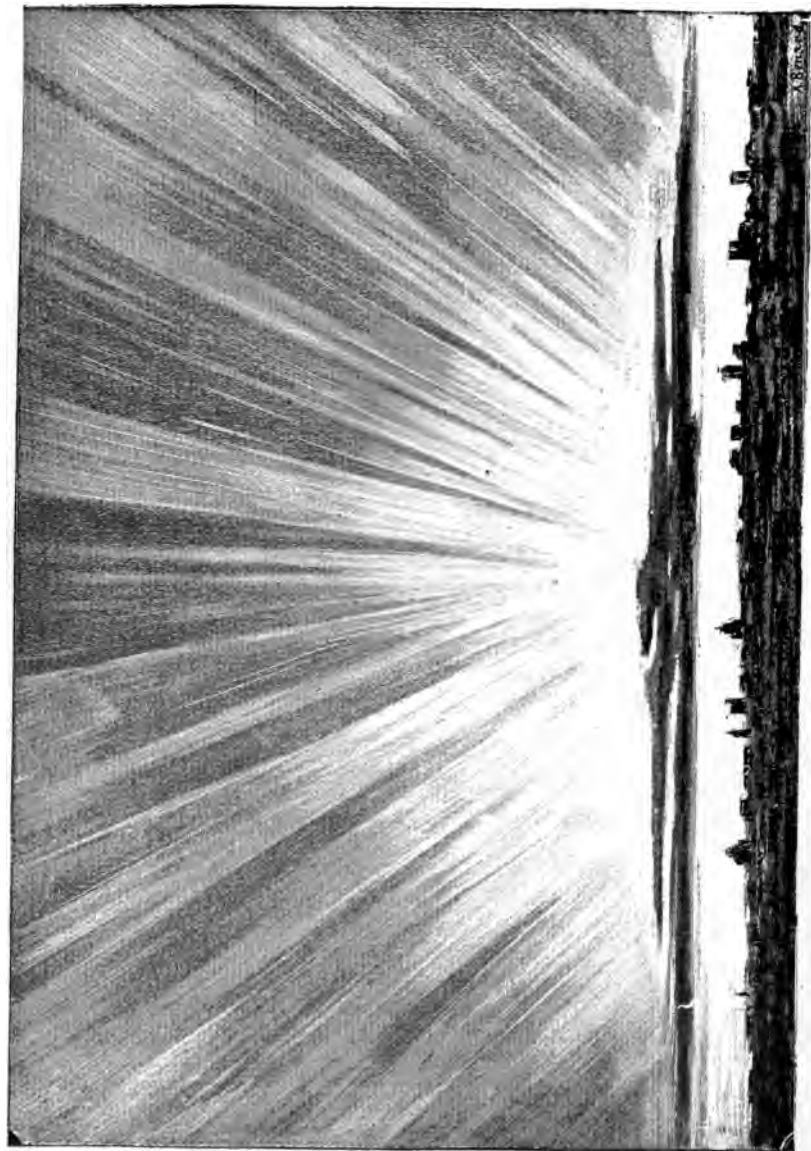


FIG. 7.—PARIS. RAYED ARC.

alis observed at Paris on October 24, 1870; an aurora of the same form was again seen at Paris the following evening. In Mairan's work¹ several similar auroras are reproduced, observed at Evreux in 1731.

Among the different movements of the striped arc we must mention, in especial, a remarkable undulatory appearance: the arc seems to move in the direction of its length with great rapidity, which may be as much as forty degrees a second. Bravais, who frequently observed this phenomenon in Lapland, suggests the same explanation as Mairan had offered; i.e. that there is no real movement of the arc, but a successive lighting up of its different parts, which remain motionless or nearly so. A ray, at first but faintly luminous, becomes suddenly very brilliant for a brief instant and returns to its former state, while the next ray brightens in its turn, and so on from one to another. It is clear that if the successive illumination of the different rays takes place with great rapidity the eye cannot distinguish whether the arc really moves as a whole or whether it is only a sort of luminous wave which passes from one end to the other of the arc. At Bossekop this movement appeared twice as frequently from west to east as in the converse direction; certain auroras showed the two movements alternately.

¹ *Traité physique et historique de l'aurore boréale*, by M. de Mairan. Paris: Imprimerie royale, 1733. (Extracted from the *Memoirs of the Royal Academy of Science*, 1731.) A second edition of this work appeared in 1754.

An appearance which often precedes or accompanies a great number of auroras, but especially those of the types which we are now considering, is the *dark segment*, a sort of segment or circle of a darker tone than the rest of the sky, which occupies the horizon to a height of about ten degrees. It is probably this dark segment which the Greeks and Latins compared to the mouth of a cavern, or to a gulf whence issue the fires of heaven; and it explains the name of gulfs which they gave to auroras, as we have indicated in the history of the phenomenon.

When the aurora is in the form of an arc the lower edge of the arc limits precisely the dark segment and seems to rest upon it. The dark segment is not formed by cloud or dense vapour, for the stars are often seen in it.

The nature of this appearance is not yet well known: the French Scientific Commission at Bossekop often had occasion to observe it, accompanied by an aurora borealis, or even alone; it is not, therefore, merely an effect of contrast. On the other hand, it is not rare to see polar auroras which are neither preceded nor accompanied by the dark segment; the two phenomena are thus, to a certain degree, independent of each other. Basing his opinion mainly on the total absence of the dark segment during a period rich in auroras, but when the serenity of the skies was remarkable, and also on the usual position of the dark segment beside the Frozen Ocean,

Bravais thinks that the origin of this phenomenon need not be sought elsewhere than in the foggy vapour which generally lies on the horizon near the Arctic Sea. In spite of the weight which is justly attached to the opinion of Bravais, the explanation which he proposes appears at least contestable; it cannot apply in any case to the numerous observations of the dark segment in stations of which the geographical situation differs markedly from that of Bossekop, and where the neighbourhood of the sea cannot be invoked. On this point there is still much uncertainty, and a great number of observations, made under circumstances of great variety, will be needed to dispel it.

To conclude the physical description of the auroras in the form of an arc we must note that in the greater number of cases the summit of the arc is in the magnetic meridian, or close to it. This rule is followed with remarkable exactitude in the case of those arcs especially which are not more than seventy degrees above the horizon. Thus at Bossekop 102 auroras of this type had at their summit a mean position which did not vary more than six or seven degrees from the magnetic meridian. But marked exceptions occur occasionally. On the night of January 16, 1839, for instance, an arc was observed at Bossekop of which the summit was eighty degrees distant from the magnetic meridian. We shall return to this point later, when we come to con-

sider the relations between the polar aurora and terrestrial magnetism.

5. *Auroral rays. Polar crowns.*—We have just seen that, in the auroras belonging to the preceding type, rays are often observed which far exceed the limits of the arc. These rays often exist alone, and constitute an important class of auroras. These are luminous columns of which the length is much greater than the breadth, and of which the direction passes, as a rule, not far from the magnetic zenith. The rays which are in the magnetic meridian appear therefore vertical, while the others strike the horizon at an angle. This law of the convergence of the rays on the magnetic zenith is not, however, absolute, for Bravais frequently saw intersecting rays which seemed to pass over each other.

The dimensions of the rays are very variable: some have a length of only two or three degrees, while others extend over more than half the vault of the sky; their width is from a fraction of a degree to two or three degrees, rarely exceeding the latter figure.

The rays are generally distinctly defined along their edges, and this, taken together with the movements of which we shall speak directly, distinguishes them from the patches and bands belonging to auroras of the second type. Their light is more brilliant than that of the arcs proper, and may be vivid enough to produce reflections in water or on snow. They are generally more luminous and more definite towards



FIG. 8.—BAY OF ISLANDS, NEWFOUNDLAND.

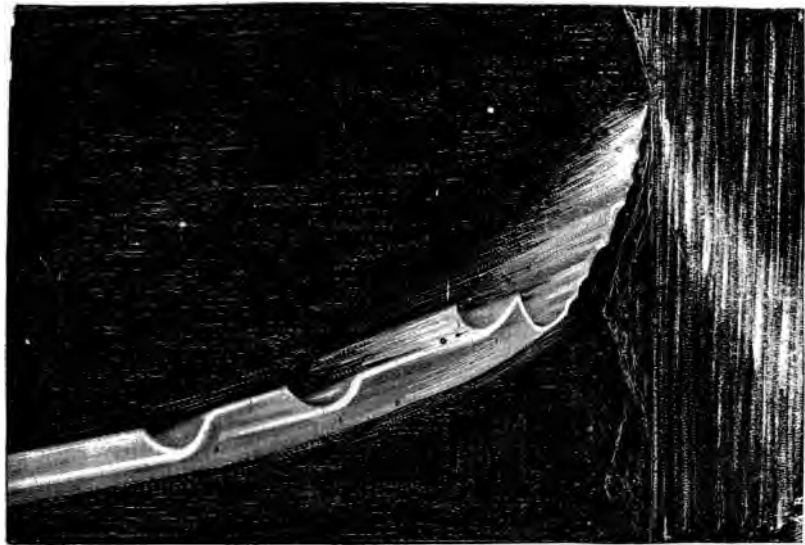


FIG. 9.—BAY OF ISLANDS, RAYED AURORA.

the foot than higher up. Finally stars may be discerned through the rays as through the arcs.

Sometimes these rays, very numerous and close together, become fused together, and produce a fragment of a striped arc, and even a complete arc; at other times they form a bundle of rays resembling cirrus clouds or fibres of asbestos. We give drawings of these groups of fibrous rays from a sketch by M. de la Monneraye. The dark rays, of which we spoke above, may also be distinguished in the illustration (fig. 8). These groups of rays often change with great rapidity; the one which we have chosen as an example presented five minutes later the aspect shown in fig. 9.

Indeed, the special characteristic of the auroral rays is their extreme variability. They are subject to two kinds of movements: the lateral movement, which displaces them in a direction parallel to the horizon from right to left, or from left to right, and the longitudinal movement, towards the zenith or towards the horizon. Both movements may be very rapid; thus Bravais observed on October 11, 1838, a ray which in twenty-seven seconds had covered a distance of ninety degrees, or half the heaven.

The longitudinal or vibratory movement offers several remarkable peculiarities. Sometimes the ray, remaining nearly in the same place, lengthens itself rapidly towards the zenith, or more frequently towards the horizon; it is then said to *dart*. Sometimes,

without altering sensibly in length, it rises and falls alternately, and is then said to *play* or to *dance*. This appearance of the aurora, fairly common in some countries, is designated by sixteenth-century authors *leaping goats* (*capræ saltantes*) or *flying fires*; it probably explains the name of *goats* bestowed by Aristotle on certain luminous phenomena observed in the sky, as we have said before; they are still known in Canada as *marionettes*, and in the Shetland Isles as *merry dancers*.

We have said above that the direction of all the rays passes, as a rule, close to the magnetic zenith of the locality. When the rays exist in all directions round this point the result is the rude figure of a crown or *glory* with rays; hence the name of boreal crown applied to this particular form. The centre of the crown may be luminous or obscure, according to the prolongation of the rays to their point of junction or their arrest at a certain distance. We give, from the drawings of M. de la Monneraye (figs. 10 and 11), the aspect of a boreal crown observed in Newfoundland in the night from September 1-2, 1892. Each of the drawings represents the half of the crown. To obtain an exact idea of the appearance the two drawings must be supposed to be joined together at their upper end, and then curved into the form of a cylinder, the lower part of fig. 10 being to the east, and that of fig. 11 to the west, the observer below, near the axis of the cylinder.



FIG. 10.—BAY OF ISLANDS. EASTERN HALF OF A CORONA BOREALIS.





FIG. 11.—BAY OF ISLANDS. WESTERN HALF OF A CORONA BOREALIS.

Sometimes the rays appear only on one side of the magnetic zenith; the crown is then incomplete: it is not closed, and forms a *wreath*. When, on the contrary, the crown is complete and furnished with very long rays, which descend almost to the horizon, the aurora forms a dome, which early authors call a tent, pavilion, cupola, &c. Finally, when the centre of the crown remains obscure, and the rays come very low down on all sides, they form round the horizon an immense luminous band.

At certain moments the rays which compose the crown enter into rapid movement, become very brilliant, and take on, instead of the yellowish white colour which is habitual to them, vivid tints of red and green. The crown then offers one of the finest manifestations of the aurora borealis. When one of these brilliant crowns forms itself in the midst of an already existing aurora, all the other lights of the aurora pale to reappear again when the crown is dissipated.

Although rare in low latitudes, the crown may be occasionally observed at a distance from the polar regions. Several examples are known in France; we have already mentioned the aurora in the form of a crown observed and described by Gregory of Tours; another, fully developed, which covered the greater part of the sky, was observed by Mairan on October 19, 1726, and is illustrated in his treatise on the aurora borealis; a distinct crown was also observed

in Paris, October 25-26, 1870. Finally, crowns have also been seen even nearer to the equator, notably that which is represented in fig. 15, which was observed at Melbourne in latitude 38° S.

6. *Auroras in the form of draperies*.—We have seen that the rays of the aurora, when they are very numerous and very close to each other, may produce either striped arcs or crowns and wreaths. When the aurora is still more developed, and its form less regular, the appearances it presents are most complicated and remarkable, and constitute the finest manifestations of the phenomenon. All the rays are grouped into a wide band, which takes the form of undulating drapery, and suggests the folds of a flag agitated by the wind.

This type of aurora presents an infinite variety. Sometimes the general form is arched, as in figs. 1 (frontispiece) and 12. At others this form disappears entirely, and the aurora really resembles ribbons or drapery (figs. 13, 14, and 18).

The more brilliant parts appear to be in relief, while others, less illuminated, seem to pass behind or to form the hollows of the folds. In most cases, since there are no means of determining exactly the real form of the aurora and the distance of its different parts from the observer, it is very difficult to decide whether this appearance of reliefs and hollows is not simply an optical illusion, due to the differences in the intensity of the rays. But in certain auroras, such

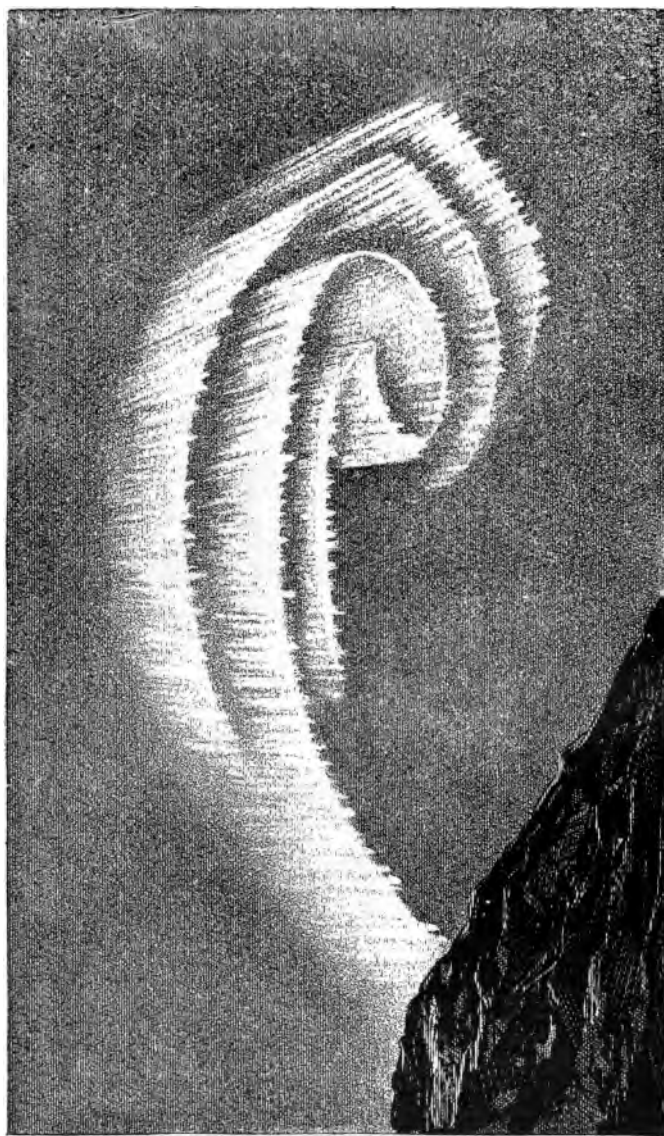


FIG. 12.—BOSSEKOP. DRAPED AURORA.

as those represented in figs. 12 and 13, it is impossible to doubt the existence of several distinct luminous planes which fold over each other.

All auroras in the form of drapery, fans, undulated arcs, are in general clearly outlined along their lower border, while the light fades out gradually above and mingles insensibly with the sky. They often display the most brilliant colours. The lower part, along the outlined edge, is a brilliant rose carmine, sometimes slightly tinged with violet. This passes into a yellowish white, which occupies as a rule the greater part of the aurora, but which occasionally disappears almost entirely. Above, where the light becomes fainter, a bluish or greenish tint appears. If we add to these colours the effect of the incessant undulatory movement which stirs the aurora we shall be able to form an idea of the splendour to which this phenomenon may attain.

Sometimes, instead of resembling a wide drapery shaken by the wind, the aurora presents the form of a long ribbon, folded back on itself several times, from the upper edge of which spring rays. This appearance was observed by Whymper in Alaska.

Finally, a last and most curious modification is that in which the drapery seems to end in a narrower ribbon; this ribbon is nebulous and affects the strangest forms, among which that of a hook (fig. 14) was frequently seen at Bossekop by the members of the French Commission.

CHAPTER III.

PHYSICAL CHARACTERISTICS OF THE POLAR AURORA.

1. *Colours of the polar aurora.*—We have already, in the description of the various forms of the polar aurora, indicated briefly the colours which they present. The most frequent is white, more or less tinged with yellow; it is the only colour of most auroras, especially those of our first three types, which are characterised by a nearly homogeneous texture and relatively slow movements.

The fainter the light of the aurora, the more the yellowish-white tint becomes milky and difficult to define, a characteristic of all faint light. When, on the other hand, the light of the aurora is vivid, it is distinctly yellow.

After yellowish white the colour which occurs most frequently is rose carmine; a few auroras with more or less defined outlines are of this tint, which is, moreover, frequently that of isolated rays.

The richest in colour of all auroras are, as has been indicated, those which are chiefly composed of rays in rapid movement, such as striped arcs,

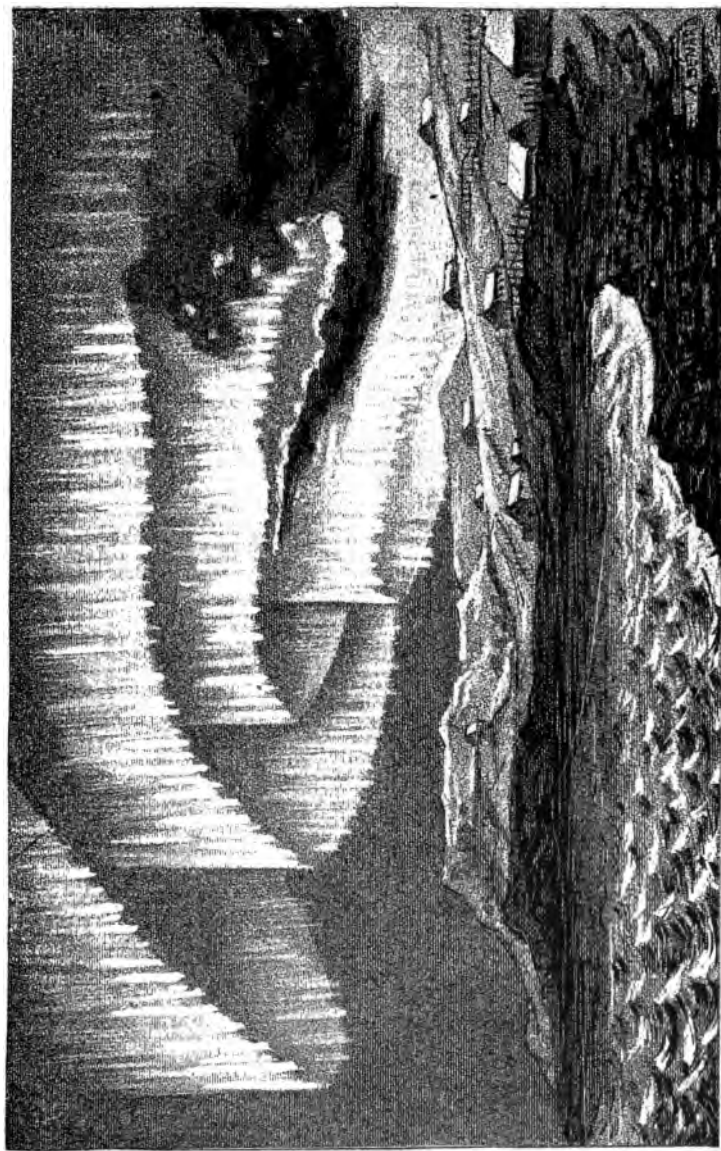


FIG. 13.—BOSSEKOP. DRAPED AURORA.

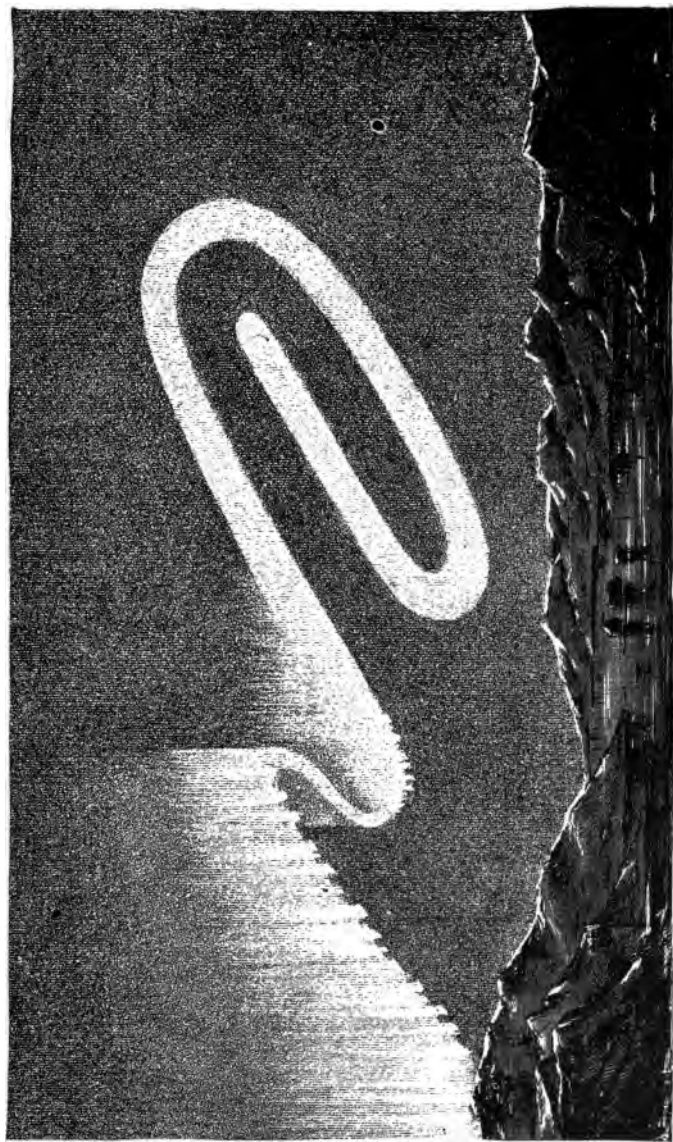


FIG. 14.—BOSEKOP. DRAPED AURORA WITH HOOK.

crowns, wreaths, and draperies. In these cases the central part of the aurora generally remains of a fine brilliant yellow tint, while the two extremities are the one red, the other green. The red is almost always towards the lower part, and also in the direction towards which the ray moves, while the green is above or behind, in regard to the direction of the movements, whether the movement be in the sense of the length of the rays (vibrating movement) or of lateral displacement (undulating movement). If the ray darts or lengthens itself downwards, the lower extremity will be red and the summit green, and these tints will be very brilliant for two reasons: first, because it is the natural order of the colours in a motionless ray; secondly, because it is in this order that they should be found from the direction of the movement. On the other hand, there is no marked coloration and the tint remains of a nearly uniform yellow when the ray lengthens itself in an upward direction; for while the red should be developed in the direction of the movement—that is, in the upper part—the upper part of the ray tends, on the contrary, to present naturally a green colour; hence the two contrary tendencies neutralise each other. The observations of Weyprecht in Franz Josef Land entirely confirm these laws already established by Bravais at Bossekop, and very few cases are known in which the distribution of colours was reversed.

The red and green tints have a corresponding

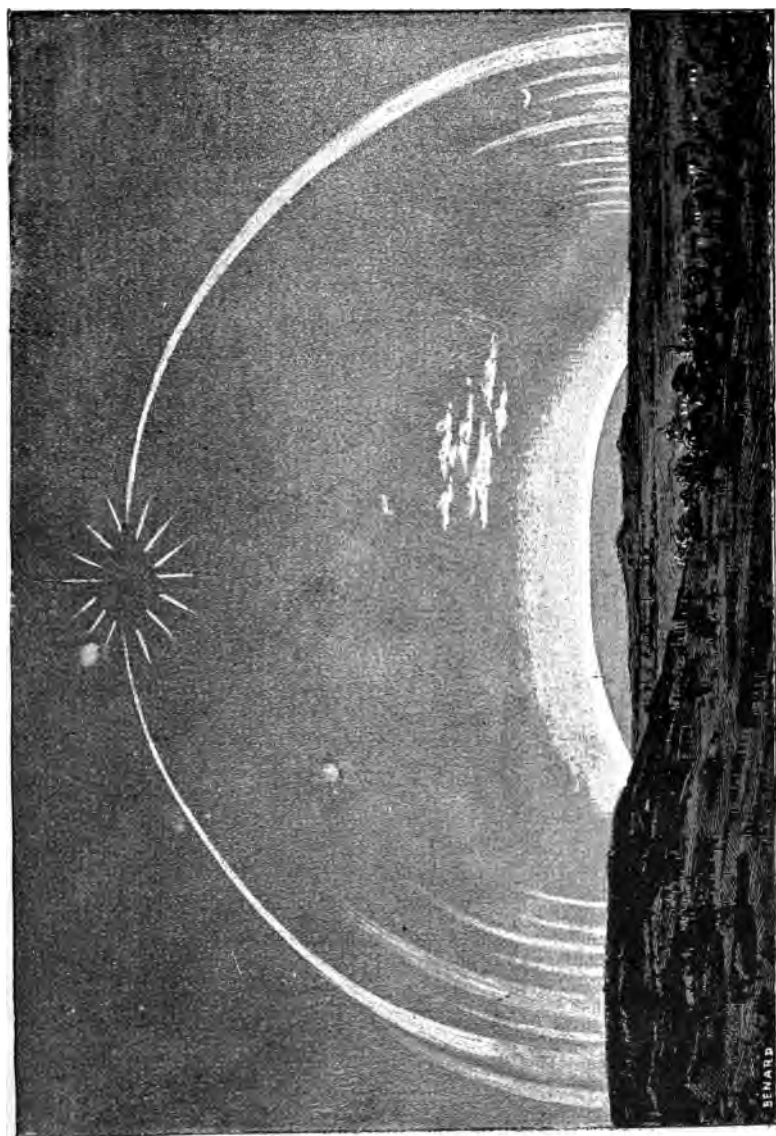
intensity : when the red is very brilliant, so also is the green. The red remains the brighter of the two tints, and is also that which fades last when fog obliterates the aurora by degrees. Independently of the relative intensity of the two tints, the fact that red light penetrates fog more easily than green may have something to do with this.

In very brilliant auroras the intermediary yellow tint may disappear altogether, and only the red and green remain. This frequently happens in the crown more particularly, of which the centre is then green while the whole periphery is red.

We have said above that isolated rays are frequently entirely red ; it is, on the contrary, very rare to see rays which are entirely green. This phenomenon only presented itself once to the French Commission during the whole of its stay at Bossekop ; on January 2, 1839, at 8.45 p.m., an arc composed solely of green rays was observed.

According to some observers it would seem that the green colour is in certain auroras replaced by a blue or violet tint ; but this last colour is extremely rare.

The brilliancy of the colours of the aurora seems to have a definite relation to the state of the atmosphere. In high latitudes particularly, the observations of Sir John Franklin, McClintock, Weyprecht, &c., have shown that the colouring of the aurora is less strong when the air is very pure, and increases





when the atmosphere becomes foggy and its transparency is diminished. Another circumstance which should be mentioned in this connection is that the auroras in the form of drapery, which are generally the richest in colour, are usually seen only in regions where the seas are open in winter and free from ice, and where, consequently, fogs are of very frequent occurrence; such are the north of Norway, Spitzbergen, and Newfoundland.

2. *Intensity of the light of polar auroras.*—The intensity of the light emitted by polar auroras is usually feeble, even in the most brilliant auroras. By the light of a very bright boreal crown, Bravais could hardly read a few words printed in the character known to printers as small text; it was very easy, on the contrary, to read the same characters by the light of the full moon, of which the apparent dimension is however much smaller than that of the aurora. The greater number of scientific men who have observed auroras in polar regions, where they are brightest, Parry, Bravais, Kane, Hayes, Weyprecht, Norden-skioeld, agree in the statement that the total illumination produced by the finest auroras is generally inferior to that of the full moon, and rarely exceeds that of the moon in her first quarter. It is clear, then, that on an equal superficial area the brilliancy of the polar aurora is far inferior to that of the moon.

An indirect proof of this fact is found when we

note the periods of the appearances of the aurora. Their frequency always diminishes when the moon is full, which shows that the general illumination of the sky produced by the moon at the full completely drowns a great number of auroras and prevents their being visible. This influence of the age of the moon on the apparent frequency of the aurora borealis had already been noted by Mairan, who found, on an average, three times as many auroras visible in that half of the lunar month which comprehends the new moon—that is, from the beginning of the last quarter to the end of the first—as in the half which comprehends the full moon, from the end of the first quarter to the beginning of the last.

There are, however, exceptional auroras which are sufficiently brilliant to appear such even when the full moon is shining; witness the aurora which was observed all over Central Europe on February 4, 1872. It has occasionally been averred that auroras have been seen in broad daylight, but the fact appears to be more than disputable. It is probable that there has been some confusion between the aurora and certain cirrus clouds which resemble it, and may even be associated with it, as we have already shown.

Another proof of the faint light given by the aurora is to be found in the facility with which the light of the stars penetrates it, without sensible diminution. The stars of the first and second

magnitudes may be discerned through the brightest aurora, and when the latter is diffused and milky the visibility of the stars extends to stars of the fourth and even of the fifth magnitudes.

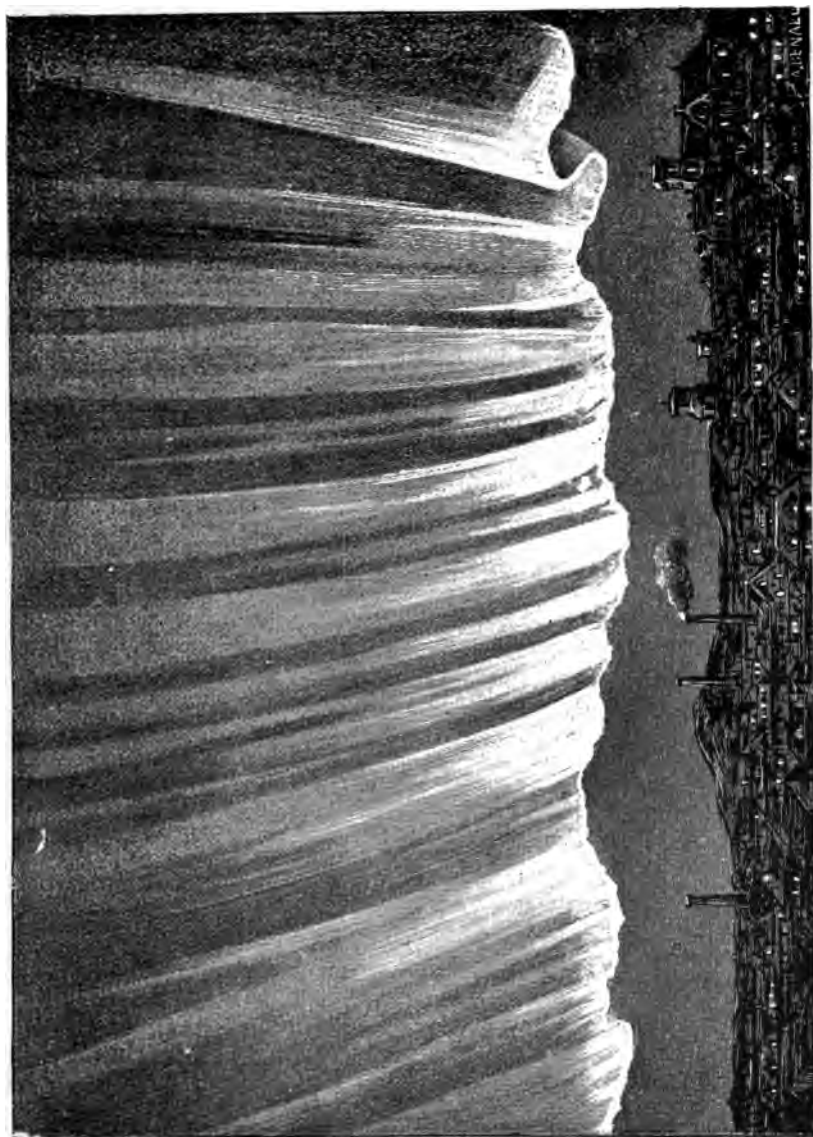
Nordenskiöld estimates, but without having made any experiments on the subject, that the motionless nebulous arc, which was the almost constant form of the aurora during the wintering of the 'Vega,' might be photographed in fifteen minutes. The sensitive plates which are now prepared would probably reduce this duration to a few minutes. The Swedish expedition which wintered on Cape Thorsen (Spitzbergen), in 1882-83, tried in vain to obtain photographs of auroras. Sophus Tromholt affirms, on the other hand, that he obtained, with an exposure of eight and a half minutes, a perceptible, though very faint, photographic impression; it is true that the part of the aurora which he tried to photograph was very faintly luminous. It does not appear that in these attempts ortho-chromatic plates have been used, though their sensibility to green and yellow rays is greater than that of ordinary plates. It may, therefore, be hoped that in the near future, by employing ortho-chromatic plates and trying the experiment with brilliant and slow-moving auroras, direct photographs of the polar aurora may be obtained; this will permit a closer study of its forms and preciser measurements of its dimensions than have hitherto been possible.

Some observers maintain that the stars scintillate

less when they are seen through the light of the aurora than when they shine in a clear sky. But this is probably an error due to the presence of fog at the time of these observations; for fog diminishes markedly the scintillation of the stars. On the contrary, it is clearly proved that the scintillation increases during an aurora. This fact, announced at the end of the last century by Uscher, has since been verified by Forbes, Necker de Saussure, Kowalski, &c. Finally, Montigny, having invented a scintillometer for measuring the degree of scintillation, has always obtained during the aurora borealis a higher number than before and after. Yet it must not be concluded that it is certainly the light of the aurora which influences the scintillation. For Montigny has also discovered that the scintillation increases equally during any magnetic disturbance, even when the latter is not accompanied by any aurora. Now, the auroras during which he noted the scintillation coincided with important magnetic perturbations. It is under these circumstances impossible to decide whether the increase of scintillation must be attributed to the aurora or to magnetic influence.

Before concluding these remarks on the properties of the light of the aurora, we may add that, according to Argelander, the passage of the light of the stars through the aurora does not alter their apparent positions.

3. *Nature of the light of the aurora.*—The nature of





the light emitted by the polar aurora and its origin may be studied in two different manners.

The first consists in ascertaining whether or no the light of auroras presents any traces of polarisation. Polarisation is a property which luminous rays acquire either by reflection or refraction, and renders them incapable, for instance, of traversing a prism of Iceland spar cut and placed at a suitable angle, or of being reflected from a mirror of glass inclined at an angle of $33^{\circ} 30'$ on the rays. By studying any light with apparatus known in optics as analysers, polariscopes, or polarimeters, it is easy to recognise whether this light is natural light emanating directly from a self-luminous body, or whether, on the contrary, it reaches the eye partially polarised, after undergoing one or more reflections or refractions.

As early as 1817 Biot studied the light of the aurora borealis in a polarimeter, in the Shetlands and in Scotland; he could not discover the smallest trace of polarisation. This result has since been confirmed by a great number of observers, Macquorn Rankine, Nordenskiöld, &c. On the other hand, Arago and Baudrimont thought they recognised very faint traces of polarisation; but this can hardly discredit the previous results, for it is sufficient for a cloud to reflect or diffuse the light of the aurora to produce at once traces of polarisation in this reflection or diffusion of the light. The complete absence of polarisation, conclusively established on several oc-

casions, is enough to prove beyond a doubt that the light of the aurora is not, like rainbows, halos, or parhelia, the result of a phenomenon of reflection or refraction, but that it is itself luminous.

This important point is confirmed and completed by the results of the spectroscopic analysis.

If the light emanating from a solid or liquid incandescent body be passed through the spectroscope, the resulting spectrum is continuous. If, on the contrary, the source of light is gaseous, the spectrum is composed of a certain number of bright lines or stripes, separated from each other by dark intervals. The number, the position, and the brilliancy of these bright lines depend on the chemical composition of the incandescent gaseous body, and this allows us to recognise by the spectrum alone the physical state and the chemical nature of the luminous body under observation.

The spectrum of the aurora borealis, studied for the first time by Angstroem in 1866, is essentially a spectrum of lines; the light of the aurora is the product, therefore, of luminous gases, and not of solid or liquid incandescent particles; neither can it be due, as has sometimes been supposed, to a reflection of the light of the sun. Among the authors who have studied this question we may mention, after Angstroem, Struve, Gettingen, Winlock, Zoellner, Vogel, Rand Capron, Norman Lockyer, Barker, Backhouse, A. Clarke, Wijkander, Lemstroem, and

lastly Carlheim Gyllenskiöld.¹ We will indicate the principal results of their researches.

Seen through a spectroscope of small dimensions, the spectrum of the aurora borealis is a single greenish-yellow line, placed between the two lines D and E of the solar spectrum. But if a large equatorial is used, so as to collect a great deal of light, and a spectroscope of great dispersive power, as many as thirteen or fourteen lines or luminous bands can be distinguished in the spectrum of the aurora. The wave length of these bands, expressed in millionths of a millimetre, is given in the accompanying table.²

All these lines do not exist simultaneously in the auroras; the brightest and most frequently seen, at least in polar regions, are 4, 7, 8, 10, and 13. The red line 1 has not yet been seen in high latitudes, although the red colour is frequent in them. The yellowish-green line, 4, is the brightest of all; it is absolutely characteristic of the polar aurora; it is often seen alone when the aurora is faint; it is even

¹ See on this branch of the subject: G. Rayet, on the 'Spectra of the Aurora Borealis,' *Journal de Physique Théorique et Appliquée*, vol. i., 1872, p. 363 (a summary of the researches of Angstroem, Struve, Winlock, Zoellner, Vogel, Ettingen); Angstroem, 'Of the Spectrum of the Aurora Borealis,' *Journal de Physique Théorique et Appliquée*, vol. iii., 1874, p. 210; Rand Capron, *Aurora and their Spectra*, London, 1879; Lemstroem, *L'Aurore Boréale*, Paris, Gauthier-Villars, 1886.

² Most authors reproduce these lengths of wave in four figures; this approximation appears to us to be purely illusory, for very often one cannot be sure even of the third figure, the measures being very difficult in the case of a phenomenon so faintly luminous and so mobile as the aurora borealis.

distinctly visible when the aurora is so faint as to be imperceptible to the naked eye.

Table of the Lines in the Spectrum of the Aurora.

Order	Length of Wave (millionths of a millimetre)	Colour and Position
1	630	Red, between c and d
2	578	Yellow, between d and e
3	566	Yellow, between d and e
4	557	Greenish yellow, between d and e
5	535	Green, between d and e d and e
6	529-526 (band)	Green, very near e
7	523	Green, between e and b
8	500	Greenish blue, between b and f
9	485	Blue, very near f
10	470	Blue, between f and g
11	464	Blue, between f and g
12	436	Blue, between f and g
13	426	Violet, between g and h
14	411	Violet, near h.

The lines 10, 11, 12 and 13 become nearly invisible in those parts of the aurora which give the red line (No. 1) to the spectroscope. Finally, the last line (No. 14) has only once been seen, in Lapland by Lemstroem and under unfavourable circumstances; the figure which indicates its length of wave is therefore more uncertain than in the case of the other lines.

There has been much discussion about the coincidences which may exist between these lines and those of known spectra—for instance, the spectrum of the electric spark in gases rarefied like those of Geissler's tubes; but no very definite conclusion has yet been arrived at. The lines 10, 12, and 13 appear to occur also in the spectrum of the electric discharge passing

through dry rarefied air ; in this spectrum are also lines near to 5, 7 and 8, though absolute coincidence cannot be affirmed. For the other lines the uncertainty is yet greater. New researches are therefore needed to clear up this question, which is the subject of much controversy.

The study of the spectra of lightning seems to furnish an argument favourable to the hypothesis which attributes to atmospheric air a certain number of the lines in the spectrum of the aurora. According to the observations of Herschel, Saussure, Vogel, C. Gyllenskiöld, &c., the spectrum of lightning gives seven brilliant lines, of which the length of wave is respectively 680, 569, 534, 526, 500, 486, and 463. These lines are very near to the lines 1, 3, 5, 6, 8, 9 and 11 of the aurora ; for some of them the coincidence appears to be exact.

In spite of these arguments opinion is still divided. While certain authors recognise no analogy between the spectrum of the aurora and that of the air, others, on the contrary, consider that the resemblance is sufficient. Angstroem, for instance, considers that the spectrum of the aurora is composed of two distinct parts ; on the one hand all the lines, except the fourth (length of wave, 557), form a first spectrum, that of rarefied air ; the conditions of pressure and temperature, very different in nature from those in laboratories, sufficing to explain all divergencies, although Angstroem does not believe in the varia-

bility of the spectra of gases. The characteristic yellow line (No. 4) constitutes in his opinion a special spectrum. This line has not been found in any known body;¹ Angstroem attributes it to a phenomenon of phosphorescence, or rather of fluorescence. Oxygen, as well as several of its combinations, is known to be phosphorescent. Moreover, the light of the polar aurora is certainly rich in ultra-violet rays capable of producing fluorescence; a drop of sulphate of quinine has been made luminous by the action of the rays of the aurora borealis, and so also the double cyanide of platinum and potassium.

It will be seen from the foregoing summary that the light of the polar aurora is not yet clearly known, notwithstanding all the researches bestowed upon it. It is one of the most regrettable lacunæ in the theory of the phenomenon, and the one to which the attention of observers should be most directed. It would be desirable to undertake in the laboratory a series of experiments on the spectrum of the electric spark in rarefied air, varying as far as possible the conditions of temperature and pressure, and also those of the discharge itself.

4. *Sound of the aurora.*—Another physical phenomenon about which there is considerable disagreement is the sound which, according to some observers, sometimes accompanies the aurora borealis.

¹ We shall see later that this line of unknown origin occurs also in the spectrum of the zodiacal light.

It is a very general belief in certain countries—for instance, in the Orkneys, in Finmark, and among the Indians of the territories round Hudson Bay—that the aurora is accompanied by a particular sound, somewhat resembling the rustling of silk. The Lapps, who also believe in the existence of this sound, compare it to the ‘cracking’ which may be heard in the joints of the reindeer when in movement. A great number of trustworthy observers maintain that they have distinctly heard this sound during very vivid auroras. Others, on the contrary, have never remarked any sound which in their opinion could reasonably be attributed to the aurora; we must note, however, that purely negative results cannot be set against a single positive and certain fact.

The members of the French Commission of Bossekop, from whose work we have already borrowed so much, did not neglect this question. Once, for instance, on January 10, 1839, during a very brilliant aurora, Bravais notes: ‘I listened with much care for possible sounds; the circumstances were favourable, the air and sea calm, yet I only heard a very faint whistling sound, coming I knew not whence, but without doubt independent of the aurora, since it was continued after the latter had faded.’

At another time, October 31, 1838, the sound appears to have been more distinct, for Lottin notes as follows: ‘At one moment I, by an instinctive movement, took my cap off to listen better, fancying

that the rays darting above our heads made a sort of crackling sound ; perhaps the sound was due to the distant steps of some one, perhaps of some animal on the hardened snow. M. Siljestroem, at some distance from me, close to his house, had the same illusion at exactly the same hour.' Finally, Thomas, a mining engineer at Kaafjord, near Bossekop, who made at the same time as the French Commission very complete observations of the aurora borealis, notes on March 10, 1840 : ' A noise resembling the rustling of straw was distinctly audible, and seemed to coincide with the darting of the rays of the aurora. This sound was only heard when the rays were near the zenith.'

In spite of these observations, which appear to be very definite, the members of the French Commission pronounced rather against the existence of any sound proper to the aurora. ' Although I dare not,' says Bravais, ' question the validity of the testimony in regard to it, we must yet conclude that this sound is very rare. Moreover, during these observations the ear may be deceived by more than one source of error against which it is impossible to be too much on one's guard ; such are the whistling of the wind, the drifting of the dry snow, the distant murmur of the sea, the crackling of snow which begins to freeze again after a temporary thaw, &c.' Siljestroem, one of Bravais' companions, concludes in almost identical terms.

It is certain that the causes of error are very numerous, and that the observer may be tempted to

attribute to the aurora many sounds which have nothing to do with it, among which we may mention as a principal one in polar regions the incessant crackling of fields of snow, and the faint sounds which always accompany the formation of small needles of ice on clear, cold nights. Much more should we reject without hesitation the observations on the sound of the aurora which have been taken in the centre of towns, beginning with that of Messier, who claimed to have heard the sound of the aurora in 1762, in the very heart of Paris. But, on the other hand, it seems very difficult to discredit altogether not only the general opinion of almost all the dwellers in the arctic regions, but also and especially a mass of testimony from competent observers.

It would even appear that this sound is audible in much lower latitudes than that of Lapland. The astronomers Brorsen and Hansteen were both absolutely convinced of the reality of such a sound. J. E. Schonfeldt affirms that he also heard it in Livonia, September 20, 1839, in absolutely still weather, in a treeless plain covered with wheat, and far from any water, so that the causes of any disturbing sound were eliminated as far as possible; the sound accompanied the rays, which darted towards the zenith. In spite of the neighbourhood of the sea, a keeper of the lighthouse on Sumburgh Head, in the Shetland Isles, was so well able to distinguish the sound proper to the aurora, that once, being in a room with closed

shutters, he became aware of the existence of an aurora from this indication alone. We must add to these observations that of the *aéronaut* Rollier, who, having left Paris, then besieged by the Prussians, on November 20, 1870, in a balloon, disembarked in Norway. He heard a persistent sound the whole time that he was in a certain cloud, which emitted a strong odour very irritating to the bronchial tubes, like that of ozone. A fine aurora borealis was observed at precisely that time.

Amid these contradictory statements it is well to be cautious, more especially as the great majority of travellers in the arctic regions have never heard the sound of the aurora.

To the external sources of error already mentioned must be added another, purely physiological: many persons hear a whistling in their ears, which under ordinary circumstances does not reach their consciousness. Perhaps this sensation is more vividly perceived when the attention is strongly directed to the observation of an aurora, especially when a ray is seen to shoot out suddenly, to which is referred instinctively a sensation of which the true source is purely subjective.

From the foregoing observations we conclude that it must not be considered as proved, but merely as possible, that during very vivid auroras a sound is produced analogous to the rustling of silk, to that which accompanies the sparks in an electric discharge,

or, finally, to the characteristic sound of the fire of St. Elmo so often observed on high mountains, such as the Pic du Midi. In any case it is still an open question.

5. *Odour of the aurora.*—The belief in the sound of the aurora rests perhaps in the mind of some people less on facts than on the analogy which exists between the aurora and the electric spark. It is probably, again, this analogy which has led some observers to think that they detected a particular odour at the time of certain auroras. Bergmann compared this odour to that of sulphur, Trevelyan to that of electricity (?); lastly, during the aurora of April 5, 1870, Sonrel at Paris and Redenbacher at Dinkensbühl in Bavaria, thought simultaneously that they perceived a peculiar acrid odour. But these observations were made in the centre of Europe—that is, at a distance from the seat of the phenomenon—and in towns, where every species of odour abounds, thus taking away almost all value from the result. Up till now no traveller in arctic regions has mentioned a particular odour as prevailing during the aurora, even in cases when, as we shall see, the aurora was certainly very near the earth. It does not seem, therefore, that we are bound to reserve our opinion on this point as on that of the sound of the aurora; no observation, made under conditions which inspire confidence, confirms the supposition that a particular odour accompanies the polar aurora.

CHAPTER IV.

EXTENT, POSITION, AND FREQUENCY OF THE POLAR
AURORA.

1. *Extent of the auroras.*—The extent of auroras is very variable: some are purely local phenomena, visible only within a narrow radius; others, on the contrary, are visible simultaneously throughout a wide area.

Local auroras appear to be more frequent in high latitudes, where alone the data in regard to them are certain. We have some valuable information on this head; unfortunately it is still insufficient, for these observations are of capital importance to the theory of the phenomenon.

During the winter of 1872-73, three polar expeditions were established in the arctic regions, and at points relatively near to one another. A Swedish mission, with Palander and Wijkander, was then wintering in the north of Spitzbergen, at Mossel Bay; at the same time the Austro-Hungarian polar expedition, on board the 'Tegetthof,' with Payer and Weyprecht, was ice-bound less than 800 miles to the east of Mossel Bay; lastly, Tobiesen was taking observations

at the Island of the Cross in the archipelago of Nova Zembla, at about 180 miles south of the 'Tegetthof.' Out of 100 days on which the Swedish mission observed auroras at Spitzbergen, there were, it is true, eighty-three on which auroras were also seen from the 'Tegetthof'; but a comparison of directions, and of the hours at which the aurora was seen at the two stations, shows that there was seldom any coincidence; very frequently nothing was seen from the 'Tegetthof' when there was an aurora over Spitzbergen, and *vice versa*, although the atmospheric conditions were favourable. Tobiesen, who was even nearer the 'Tegetthof,' observed thirty-five auroras on days when Weyprecht also saw them; but, on the other hand, he notes three which were completely invisible to the Austro-Hungarian expedition, although the distance between the two stations was only 250 kilometres.

So also the 'Alert' and the 'Discovery,' the two ships of the English polar expedition under Captain Nares, wintering in Smith Strait in 1874-75 at a distance of seventy-five miles from each other, only seven times observed a coincidence in their notes of the aurora borealis.

We shall give other examples, when we come to discuss the observations relating to the height of auroras, of the local character of many manifestations of the phenomenon.

In contrast to these local auroras there have been others, especially in lower latitudes, which were visible

simultaneously over a very wide area. In the night of August, 28-29, 1859, for instance, the same aurora borealis was seen at the same time over the whole of Europe, in the west of Africa, on the Atlantic, in the whole of North America, and as far as Cuba. The limit of visibility was marked by a line passing from California a little south of Sacramento; it crossed the United States, passing to the south of Jamaica, and ended at St. George d'Elmina on the coast of Guinea.

Four days later, on the night of September 1-2, 1859, another aurora was visible over the whole of North America; its limit of visibility included Guadeloupe, Jamaica, Cuba, and the Sandwich Isles. At the time of this aurora it was broad day in Europe, and this probably is the only reason it was not observed here; for it manifested its presence very clearly by magnetic disturbance and considerable interruptions in the telegraphic service, phenomena which have an undoubted connection with the aurora borealis, as we shall show later.

Perhaps the most remarkable fact in connection with these auroras of wide extent is that they are often produced simultaneously in both hemispheres. During the two great auroras of 1859 mentioned above, very remarkable auroras were also observed in Australia and at Santiago in Chili. It was the same with the great aurora of February 4, 1872. At that date an aurora borealis was observed in the immense

zone limited on the north by a line drawn from Ienisseisk in Siberia to the Bay of Polaris, at the northern extremity of Greenland, and to the south by another line passing through Bombay, Syene (Upper Egypt), and Florida. This zone thus included a great part of Asia, the whole of Europe, and the north of Africa and of the Atlantic. Just at the same hour an aurora australis was visible over a great part of the southern hemisphere, notably in Australia, Mauritius, Réunion, and Natal. The regions of visibility of the two auroras were thus separated only by a zone of about twenty degrees of latitude on either side the equator.

It would even seem that this simultaneity of the aurora borealis and australis is the rule and not the exception. Data with regard to the southern hemisphere are often wanting, yet we possess an uninterrupted series of eight years of observations taken at Hobart Town in Tasmania, from 1841 to 1848, during which thirty-four auroras were reckoned. Now, every time that an aurora was seen at Hobart Town an aurora borealis was observed in the northern hemisphere, or, at least, if it were day-time in Europe, there were those important magnetic perturbations which accompany polar auroras.

If it be remembered that the presence of the sun above the horizon prevents a given aurora from being seen over half the surface of the globe, and if we remark that, in the cases cited above, the aurora was seen in

the whole of that part of the mean latitudes of the globe where it was night at the time of its appearance, it will not seem unreasonable to admit that at certain moments the lights of the double polar aurora may entirely envelop the earth, with the exception of an equatorial zone of a width of about forty degrees.

This wide extent contrasts strangely with the very restricted area of other auroras, of which the limit of visibility is some few hundreds of square miles. It seems difficult to attribute the two phenomena to the same cause. We shall see that subsequent considerations lead to the same conclusion, and that we must separate entirely the great auroras, visible in low latitudes and occurring but rarely, from the very frequent and quite local auroras which are seen mainly in polar latitudes.

2. *Height of the aurora.*—It is more than a century since the earliest attempts were made to measure the height above the surface of the earth of the luminous phenomena which constitute the aurora. They date from 1726, and are the work of Mairan. Before his time it was believed that the seat of the aurora was very near the earth, an opinion founded not on precise data, but solely on the rapidity of the movements of the rays and of the form of the aurora—a rapidity which it seemed impossible to reconcile with any great distance.

The method proposed by Mairan to determine the

height of the aurora has been employed since by most observers, with certain modifications in detail. It consists in measuring at the same moment, from two stations at a sufficient distance apart, and of which the distance from each other is exactly known, the angular height of a given point of the aurora above the horizon, and its azimuth. A simple calculation in trigonometry then gives, as in ordinary triangulation, the absolute height of the aurora above the horizon, and its distance from the two stations.

This process, which is very simple in theory, is, however, extremely difficult of application. First of all it is essential that the observers should choose exactly the same point in the aurora; and it is also necessary, on account of the rapid movements of most auroras, that there should be an absolute simultaneity of the two observations. This last condition is now comparatively easy of realisation, if the two stations are connected by telegraph or telephone. But it may be said that the first condition is never realised. For an aurora does not present distinct marks, easily recognisable from the two stations, such as those which are used in surveying; even at a slight distance the effects of perspective completely modify the aspect of an aurora. To eliminate this source of error it has been proposed to choose that point of the lower border of the arc which is in the vertical plane of the two stations; this method would give a satisfactory result if the lower border

were clearly defined, and if the aurora were reduced to thin film. But nothing authorises this last hypothesis ; on the contrary, it is certain that the aurora has a considerable depth, so that its lower border, or what appears such to each station, corresponds in fact, as a result of perspective, to different points. And, further, the lower edge, which is always the clearer, is yet itself always a little softened off ; what is taken for the edge is the point where the light is most intense—that is to say, which corresponds to the visual ray which meets the luminous mass at its greatest thickness. Now, it is certain that these visual rays do not coincide for the two stations. There is, then, very little likelihood that the points of the aurora chosen at two stations even at no great distance from each other will be the same ; we shall find manifest proofs of this in the discussion of certain observations. For all these reasons we must guard ourselves against attributing to the figures obtained for the height of auroras an exactitude which they cannot possess. There is a margin of possible error which in some cases attains to as much as half the numbers given. These are not, properly speaking, measures, but indications of approximate size and distance.

The first results attained by Mairan were quite contradictory to the then received opinion. Instead of finding that the aurora was at no considerable height above the surface of the earth, he always found the contrary : 266 leagues for the aurora of October 19,

1726; 250 leagues for that of October 8, 1731; 160 leagues for a sort of coloured shield which was observed during the aurora of February 15, 1730, &c. Mairan hence concludes, from all the measures that he was able to make, that the auroras seen in France in his time were situated at heights comprised between 100 and 300 leagues.

More recent observations taken in Europe lead to similar results. Thus, from an analysis of all the observations collected about the great aurora of October 25, 1870, Floegel¹ deduces the following conclusions: the altitude of the base of the rays is very variable; it is usually comprised between 150 and 250 kilometres (93 to 155 miles), but its extreme limits attain perhaps 100 and 300 kilometres (62 and 186 miles). As to the summits of the rays, they often reach a greater height than 500 kilometres (310 miles); it is even probable that they pass 750 kilometres (565 miles); but they appear never to reach 1,500 kilometres (930 miles).

However large these numbers may appear, they are not physically impossible, for falling stars have been seen of which the height was certainly some hundreds of kilometres, which proves that at these enormous altitudes there is still an appreciable quantity of air.

All the measures taken, up to this day, of auroras

¹ *Zeitschrift der österreichischen Gesellschaft für Meteorologie*, vol. vi. 1871.

in mean latitudes have given similar results. Thus observations of the aurora of October 22, 1804, at Berlin and Halle gave Gilbert a height of 377 kilometres, or 223 miles; it is true that, according to observations taken in Sweden, Baron Wrede estimated the height of the same aurora at 1,313 kilometres, or 815 miles, nearly four times as high—a fact which justifies our remark on the untrustworthy nature of these figures.

Other observations, made in England, and compared by Dalton, Cavendish, Potter, Airy, &c., have given numbers varying between 80 and 160 kilometres (fifty to ninety-three miles).

Loomis¹ has also determined the height of the two auroras observed in the United States in 1859, one on August 28, the other on September 2. These two auroras appeared to shine in the zenith at the more northern stations, whereas they were only some few degrees above the horizon in the most southern stations. A comparison of the observations gave seventy kilometres as the height of the lower edge of the arc of the first aurora, and numbers varying from twenty-three to seventy-five kilometres for the second. The upper edge had a height of 800 kilometres in the first case, and 730 kilometres in the second.

Observing all necessary caution as to the accuracy of these numbers, it is yet certain that all the obser-

¹ E. Loomis, 'The Aurora Borealis,' *Reports of Smithsonian Institution*, 1865.


vations agree sufficiently to show that in mean latitudes the height of the aurora is considerable ; it appears rarely to be less than seventy or eighty kilometres for the lowest part of the aurora, while the summit sometimes attains several hundred kilometres.

The French Commission, during its stay at Bossekop, made many measurements of the height of the aurora. Bravais and Lottin observed simultaneously at Bossekop and Jupvig, at a distance of about sixteen kilometres, or ten miles from each other. In spite of all the difficulties which they encountered, they thought they might conclude from the sum of their measures that the mean height of the arcs of the aurora borealis at Bossekop is from 100 to 150 kilometres above the surface of the earth. If we examine their observations in detail we shall see that in a certain number of cases they found for the parallax of the aurora, or the difference of the apparent heights above the horizon, a negative number ; that is to say that the aurora, although seen towards the north, presented at the northern station a less apparent height than at the southern station, which is manifestly impossible. This result can only be explained, as we have already shown, in one way : the observers saw the aurora under different forms, and really chose two different points.

Bravais has indicated another method for measuring the height of auroras, which requires only one

observer, but necessitates, on the other hand, an hypothesis which is at least disputable. This second method consists in measuring the apparent width of the auroral bands, which pass through the zenith, at their summit and at their foot. If we then assume with Bravais that the auroral band is parallel to the surface of the earth—that is to say, that all parts of it are at the same height—it is easy to calculate, according to the laws of perspective, the apparent variation in width which the band should present at its different points, and its absolute height above the earth. Bravais used this method as a verification of the first; the results were nearly in agreement with the others; therefore Bravais thought he might consider it as proved that ‘the height of the arcs of the aurora borealis is as a rule between 100 and 200 kilometres above the surface of the earth.’

In the article from which we have already quoted on the auroras observed during the wintering of the ‘Vega,’ Nordenskiöld has calculated the height of the homogeneous arc, which was the almost constant form of the aurora in that district and at that time, by an indirect method which is something like Bravais’ second plan. He measured only the angular height of the summit of the arc and the opening of the arc, or width of the angle of the two points where the arc cuts the horizon. To make the calculation with these data only, Nordenskiöld assumes that the arc is circular, and situated in a



plane perpendicular to the radius of the earth which terminates in a point near the magnetic pole (lat. 80° N., long. 83° west of Paris). He concludes that the plane which contains the auroral arc, and which is perpendicular to this radius, cuts it at a distance of 125 kilometres below the surface of the earth. In this plane the ring of auroral light would have its lower edge at about 200 kilometres above the surface of the earth.

The hypothesis of Nordenskiöld requires more confirmation. But it will be seen that it leads, with regard to the height of the aurora, to a conclusion similar to that arrived at by other methods.

In contradiction to all these observations which assign an enormous height to the aurora borealis, we might quote many others which lead to results entirely different.


Farquharson, who had organised corresponding observatories in different parts of Scotland, found that the auroras often illuminated the lower surface of the clouds. In particular, simultaneous observations taken on December 20, 1829, at Alford and Tillynessle, assign an altitude of only 1,220 metres, or very nearly 4,000 feet. From observations in the Shetland and Farøe Isles, Trevelyan believes that the aurora often descends to fifteen metres only (fifty feet) above the sea-level.

Parry and two of his companions observed at Port Bowen, on January 27, 1825, a ray of the aurora

borealis projected between their ship and the shore, which was about a mile and three-quarters distant, and reached an altitude of about 670 feet only. Ross and Scherer also mention several times auroral rays interposed between their two ships, or between the ships and icebergs. Finally, Sir John Franklin and many others affirm that they have seen the under surface of clouds lit up by the aurora, which certainly shone between these and the earth.

Similar appearances were observed by the French Commission in Lapland. During the aurora of September 20, 1838, Bravais notes : ' A very large ray to the south-west ; it is evidently lower than the clouds. These clouds are clearly coloured from below ; the lights are lower than the clouds.' Later, on October 31, Lottin observes a ray of the aurora between him and the mountains. Nevertheless, in spite of his own assertions, Bravais, in the general summary of his observations, explains these appearances as optical illusions. He attributes, for instance, the prolongation of the rays in front of a mountain to the reflection of the light of the snow crystals, and finally rejects the hypothesis of the proximity of the aurora, doubtless because it was in open contradiction with the results of his direct measurements as given above.

Since this date the most skilled observers of this class of phenomena have collected a great number of data which place the matter beyond a doubt.



Lemstroem,¹ during the Swedish expedition to Spitzbergen of 1868, several times saw auroral lights projected between him and the mountains situated at a short distance; these lights, studied in the spectroscope, showed moreover the yellowish-green line characteristic of the aurora borealis. During a journey in the north of Finland, in the winter of 1871-1872, the same observer² frequently perceived auroral rays below the clouds, and at a less height than the summit of the mountains. Once even he found himself in the midst of an aurora; although he did not see in the heavens any distinct form of an aurora, the spectroscope gave in all directions the characteristic greenish-yellow line, even in directions where there was no snow, so that it was impossible to explain these effects of light by reflection.

Hildebrandsson³ also mentions several auroras seen in Sweden in the region of clouds, or even below them. The second series of the 'Journal of the International Polar Commission' (1882) contains (p. 54) a summary of the very interesting results obtained at Ivigtut in Greenland by an engineer, Fritz. Measurements taken simultaneously from two stations (March 15, 1872) showed him that the aurora was 690 feet above the sea level and 1,800 feet from one of the stations. On February 26 of the same year the

¹ *Zeitschrift der österreichischen Gesellschaft für Meteorologie*, vol. vi. 1871.

² *Ibid.* vol. vii. 1872.

³ *Ibid.* vol. xi. 1876.

aurora was only at a height of 180 feet, and at a distance of 360 feet. These auroras belonged, not to the type of homogeneous arcs (third class), but to our fifth class (auroras with rays). Moreover, their movements appear to depend almost entirely on the configuration of the land ; on the coast of Greenland they come as a rule from Davis Strait, and enter the fiords or valleys, up which they pass. Thus it appears that those who are in the fiord often have the impression that they are very near the aurora. Lastly, the movement of these auroras appears to be checked when the wind is strongly against them. These auroras, situated very near the ground, often display the phenomena which we described in Chapter II. (Auroras of the second class, p. 14).

The most recent observations on polar auroras, made at the time of the International Arctic Expedition of 1882-83, confirm the last results enumerated, and have, as a rule, given fairly low figures for the height of the aurora.

Measurements taken at Sodankyla, in Lapland, gave for the height of the aurora numbers included between 20 and 30 kilometres (12 and 18 miles), recording only the observations in which the difference of the angular height of the arc above the horizon in the two stations, or parallax of the aurora, is more than one degree—that is to say, determined with some degree of certainty. In the course of these observations new proofs were furnished of the uncertainty of these

measurements. Thus out of eight observations made on December 8, 1882, on the same aurora from two stations connected by telephone and situated only at a distance of only three miles, six gave negative parallaxes; the two observers, in spite of the short distance which separated them, no longer saw the same phenomenon. This is shown with even greater certainty by the fact that a telephonic message to the northern station, 'Measure from the red ray,' could not be obeyed because at that station no trace of a red ray was apparent.

During the same winter (1882-83) the Danish expedition stationed at Godthaab (Greenland), under the direction of Paulsen, organised, to measure the height of the aurora, two stations situated at a distance of 58 kilometres from each other (36 miles) and on the same magnetic meridian. The point chosen was in the vertical plane passing through both stations, and the time was indicated by rockets. Out of thirty-two measurements so taken, under conditions for obtaining accuracy rarely realised elsewhere, only ten gave a parallax of less than a degree; in the other twenty-two cases, the height of the aurora averaged 19 kilometres (12 miles), the lowest point of any aurora being 600 metres (2,000 feet) and the highest 67 kilometres, 800 metres (about 42 miles). Two auroras, at a height of 4,500 feet and 1,900 feet respectively, hung over the gulf between the two points of observation; both were draped auroras.

From all this evidence we are entitled to conclude that the altitude of polar auroras varies within very wide limits, and that, in spite of the opinion of certain authors, it is certainly possible to observe auroral manifestations quite near the surface of the earth, some even very complicated, such as the draped auroras ; the observations of Paulsen, just mentioned, leave no doubt on this head.

But let us distinguish. In mean latitudes, in France and Central Europe, all measurements of the height of the aurora have always given very high numbers. The figures are no doubt often disputable ; but, allowing for all uncertainty, it seems impossible to reduce them to a few miles, as in the case of some of the measurements taken in polar regions. It is only in latitudes above the 55th or 60th parallel that auroras are undoubtedly found at a much lower level, and sometimes even quite near the surface of the earth. It seems, then, lawful to assume that the mean height at which the aurora is produced diminishes as we approach the poles. Perhaps exceeding 100 kilometres (60 miles) in low latitudes, it descends to some tens of miles in the Arctic regions, and may even be quite near the ground.

It must be noted that the extent of the aurora appears to bear a certain relation to its height. The extensive auroras—those, for instance, which are seen simultaneously in the two hemispheres—appear to shine from an immense height. On the other

hand, the auroras which are at low levels are always very limited in area, or even purely local. This appears to be another point in favour of the opinion already stated—namely, that these two categories of auroras are really distinct phenomena, both in their properties and in their origin. We shall, in subsequent pages, adduce other facts in support of this theory.

8. *Frequency of the polar auroras.*—Under this title we comprehend only the study of the absolute frequency of the aurora; that is to say, the total number of auroras observed in a given country during a long period of time—one or two centuries, for instance. The more or less regular variations to which this frequency is subject in the same country, in the course of the year or from one year to another, will be treated in the next chapter.

The frequency of the aurora is determined from a study of the catalogues of the aurora borealis and australis, which give a list of all the auroras observed in modern times, and of those of antiquity of which any trace can be found in histories and chronicles. Of course the data increase as we approach our own day, so that the number of auroras appears to be continually augmenting. But in reality there is nothing to authorise such a supposition.

The first of these catalogues is that which Mairan published, in 1733, in his treatise on the aurora borealis. The most complete is that of Hermann

Fritz,¹ which includes the enumeration of all the auroras observed between 1700 and 1872. In this catalogue are summed up all those which had previously appeared, notably those of Mairan, Loomis, Argelander, &c. Some few others have been published relating to special districts; for instance, that of Rubenson for Sweden and Mobreg for Finland. Most of the following figures are borrowed from the work of H. Fritz.

As the absolute frequency of the aurora is not the same at all epochs, either on account of periodic variation or as a consequence of insufficient observation in earlier times, Fritz begins by reducing all the numbers proportionately to the same period—1700–1872. During these 172 years, 4,834 auroras were observed in that part of Europe comprised between the latitudes 46 and 55, giving an average of twenty-eight auroras a year. If in a given country a certain number, *A*, of auroras has been observed in a definite time, and if during the same period we find in the catalogue a number of auroras, *B*, for the part of Europe which we have indicated, the probable mean number of auroras, *N*, which should have been seen in a year in the country under consideration from 1700 to 1872, if observations had been taken all that time, will be

$$N = 28 \times \frac{A}{B}$$

¹ *Verzeichniss beobachteter Polarlichter*, zusammengestellt von H. Fritz. Gedruckt auf Kosten der K. Akademie der Wissenschaften in Wien. Vienna, 1873.

It is in this way that Fritz obtained comparative numbers for all countries, and, by indicating these numbers on a map, the geographical distribution of the frequency of the aurora. We reproduce (fig. 16) the map which, according to Fritz, gives this distribution. The irregular ellipses traced on this map pass through points where the frequency of the aurora is the same.

The first line, marked 0·1, corresponds to those regions where, on an average, 0·1 aurora is seen in a year, or, in other words, one aurora in ten years. In the Old World this line passes through the Straits of Gibraltar, the south of Italy, Constantinople, the Caspian Sea, and crosses Asia at about latitude 47°. In America it cuts Mexico, and touches the south of Cuba. Within this line the frequency of the aurora increases rapidly. One aurora a year is the average at San Francisco, New Orleans, the north-west corner of Spain, at Bordeaux, Lyons, Vienna, and Tobolsk. The average at Paris is a little less than four, and a little more at Berlin ; it is six in London, nine at St. Petersburg, ten at Liverpool and Copenhagen. Beyond this point the increase is very rapid ; the line which corresponds to thirty auroras a year passes in Europe through the north of Ireland, the middle of Scotland, Christiania, and the White Sea ; in America, through the south of Alaska, Lake Superior, Quebec, New Scotland, and the south of Newfoundland. Lastly, about one hundred auroras are seen in the year at the Faroe

Islands, Tronthiem, the south of Nova Zembla, the northern coast of Siberia, Behring Strait, and in the south of Hudson Bay and Labrador.

Fritz' map must undoubtedly be regarded only as a first attempt; in many parts the lines have been drawn from observations which extend over too short a period of time, or are themselves in insufficient numbers, and will probably be modified by further study. It seems to us, for instance, that the number of auroras indicated for Newfoundland is probably far too low, judging from the account of sailors who have spent a long time in those seas. But these modifications will apply only to matters of detail, and the map may be accepted as showing in its broad lines the present state of our knowledge of the geographic distribution of the aurora.

It will be noticed that the curves of equal frequency of the aurora borealis are neither circular, nor centred on the North Pole; they are rude ovals, of which the centre is in about 80° north latitude and 75° west longitude (from Paris)—that is to say, close to the western coast of Smith Strait, to the north of Baffin Bay. We shall call this point, for brevity's sake, the pole of the aurora.

The frequency of the aurora does not increase continually as we approach the pole of the aurora; the increase in frequency, at first very rapid, as we have seen, slackens and finally ceases altogether. On the map, within the curve marked 100, is another,

drawn with a heavier line and lettered *maximum*; it passes by the North Cape, the northern extremity of Nova Zembla, the North East Cape of Siberia (Cape Cheliouskine), and cuts the meridian of Behring Strait at latitude 70° ; then it enters America a little to the west of Barrow Point, crosses Hudson Bay and Labrador, and passes well to the south of Greenland and Iceland. This curve unites all the points where the aurora is most frequent, so that the number diminishes as well within as without this line as we recede from it. The whole region in which the polar expeditions commonly winter—Melville Island, Baffin Bay, Smith Strait, &c.—are within this line and at a considerable distance from it. The travellers who have sojourned in these regions have all testified to the fact that the auroras are far less frequent than further to the south—the coasts of Labrador and Iceland, for instance—they are also much less brilliant. This diminution of the auroras in frequency and in intensity has been marked by Parry, Sir John Ross, Kane, Hayes, Nares, &c.; it is also manifest in the observations collected at the meteorological stations established by the Danish Government along the coast of Greenland.

When, therefore, people speak of the frequency of the aurora in the polar regions we must not take this expression literally; on the contrary, auroras are far less numerous in the polar region proper than

further to the south. The zone of the maximum frequency descends even below latitude 60° in the whole region comprised between the middle of Hudson's Bay and the meridian which touches the eastern coast of Greenland.

The observations of the polar aurora in the southern hemisphere are too few in number, and taken from stations too far removed from the Antarctic regions, to permit us to formulate any statement of the geographical distribution or of the frequency of the aurora in that hemisphere.

4. *Direction in which the aurora is seen.*—We have already briefly indicated, in describing the principal forms of the aurora, that the summit of the auroras in the form of an arc, or the centre of the corona, is generally near the magnetic meridian; we shall recur to this matter when we come to treat of the relations which exist between the aurora and terrestrial magnetism. But there is another more general question: to determine whether the aurora manifests itself habitually in the northern or the southern quarter of the horizon.

In France and throughout Central Europe the aurora borealis is nearly always seen towards the north, although some pass the zenith, and even display themselves entirely on the southern side. These cases are extremely rare, yet they may occur even in low latitudes. Thus on September 11, 1860, J. Schmidt probably saw at Athens an aurora borealis


towards the south, which he took for an aurora australis.

As we go northwards these cases of auroras seen in the south become more and more frequent, in Sweden and Norway for example, and we finally reach a zone in which the aurora is quite as often seen in the one quarter as in the other ; the position of this *zone of neutral direction* is indicated by a dotted line on the map on page 133. This zone is situated within that of the maximum of the frequency of the aurora, and at but little distance from it, except in the neighbourhood of Iceland, where the two zones are a little further apart. In all places within this zone of neutral direction the aurora is far more often seen in the southern quarter of the horizon. It is the case in Spitzbergen, Greenland, and all Arctic countries ; thus the observations of Palander in Mossel Bay (Spitzbergen) give south 27° east as the mean direction of the summit of the arcs ; the number of the auroras seen in the south is to that of the auroras seen to the north as eight is to three. So in all the Greenland stations the aurora is more frequently seen in the south than in the north. At Upernavik, for instance, out of one hundred auroras, eighty-one were seen between the south-west and south-east, fourteen in the east, one in the west, and four only between north-west and north-east. That is, there are twenty times as many auroras in the southern quarter of the horizon as in the northern. It thus seems to be

well established that the mean position of the aurora borealis is precisely at the zenith of the points situated on the line of neutral direction.

The observations collected at the time of the international polar expeditions in 1882-83 furnished results which agree at all points with those of earlier date. For example, at Fort Rae, on the shores of the Great Slave Lake in North-Western Canada, and at Nain in Labrador, the number of northern auroras was four times as great as that of southern; these two stations are therefore, as the map indicates, outside the zone of neutral direction. On the other hand, the number of southern auroras was twice as great as that of northern at Jan Mayen Island and four times as great at Kingawa Fiord (in Cumberland Strait). These two points are both within the zone of neutral direction, the second being the furthest from it.

With these conclusions we may compare those of Nordenskiöld in his work on the auroras observed during the wintering of the 'Vega,' from which we have already quoted (see page 62). After having compared the auroras which he observed at the entry of Behring Strait with those of other Arctic regions, Nordenskiöld thinks it possible to explain the principal appearances by the hypothesis of a luminous ring encircling the earth almost constantly in the Arctic regions, the plane of this ring being perpendicular to a radius of the earth passing through



its surface at lat. 80° north and long. 83° west (Paris). This point is nearly that of the pole of the aurora ; indeed, it may be said to be the same, when we consider the uncertainties which govern the determination of the two points.

This luminous ring or aureola would be exactly above the line of neutral direction, and would have a radius of about 2,000 kilometres, or 1,230 miles ; its height above those points of the surface of the earth which have it directly at the zenith would be 200 kilometres, or 124 miles. A second and larger luminous ring might be in the same plane as the first.

This hypothesis, which accounts satisfactorily for some of the phenomena, presents certain difficulties. In the first place it assigns to the neutral zone a circular form, whereas on Fritz' map it is distinctly ovoid ; the uncertainties which may be felt as to the details of this map do not appear to be of a nature to modify the curves in a sense favourable to Nordenskiöld's theory ; rather the contrary seems probable. Moreover, Lemstroem has pointed out that the phenomena observed by Nordenskiöld are susceptible of a different explanation ; the same appearance would be produced by a luminous arc of 120 kilometres wide (75 miles) and of which the height was only 22 kilometres (between 7 and 8 miles). Lastly, nothing seems to show that the motionless arc which was the almost constant form of the aurora during

the wintering of the 'Vega' is a general phenomenon, nor that it would be reproduced in the same region at a different time. As we shall see, the polar aurora is a phenomenon which has a marked periodicity, and it seems to be proved that the dominant forms of the aurora depend, not only on topographical conditions, but also in a given place on the epoch of the period, on the season, and many other circumstances. In fact, in no other region, even situated also close to the maximum zone—in Lapland, for instance—has the same form been so constantly observed as during the wintering of the 'Vega.' The hypotheses of Nordenskiöld appear, therefore, to require further confirmation; it was in any case of interest to compare them with the results obtained by Fritz solely by the study of the comparative frequency of the aurora and of the direction in which they are observed in different countries.

CHAPTER V.

PERIODICITY OF THE POLAR AURORA.

IN our study of the periodicity of the polar aurora we shall consider successively: (1) the diurnal period—that is to say, the variation of the mean frequency of the aurora at different hours of the day; (2) the annual period, or variation of the frequency of the aurora according to the month and season; (3) the so-called secular period, of which the cycle may include a greater or less number of years.

1. *Diurnal period of the aurora.*—The collective observations of all countries show that the appearance of the aurora borealis presents undoubtedly a diurnal period—that is to say, that the aurora has a manifest tendency to show itself at certain hours rather than at others. This periodicity exists not only for the aurora in general, but for each of its forms in particular. Thus the appearance of arcs, rays, discs, or patches, the hour when the rays take colours, attain their maximum brilliancy, undulate, and finally disappear, seem not to be a matter of chance.

At Bossekop, for instance, Bravais found that the

first appearance of the auroral arc took place at an average hour of 7.50 P.M., that of the rays at 8.30 P.M., and that of the discs at 11.20; the appearance which we have called 'palpitating' lights generally only appeared towards 1.30 A.M. Lastly, the coloured auroras manifested themselves especially between 10 and 11 P.M.; it is also at this hour that the auroras have, as a rule, their greatest intensity. It is not possible, except in winter in the Arctic regions, to determine the hour of the minimum of auroras, since they are indistinguishable by daylight. Seven or eight cases are known in which an aurora is said to have been observed in the daytime; but most of these observations were taken in northern countries, in winter, and at an hour when the daylight was already fading; in the other cases it is not certain that the observers did not mistake for an aurora certain clouds which, as we have said, offer a close analogy of form with the aurora borealis. We do not therefore know the law of the diurnal distribution of the auroras, nor, consequently, the hour of their minimum frequency.

The hour of the maximum appears, on the contrary, to be clearly determined; it occurs, as a rule, in the first half of the night, and grows later as the latitude increases. Thus the mean hour of the maximum is 8.45 P.M. at Prague; 9.15 at Oxford; 9.30 at Upsala; 10 at Christiania and in Canada; 10.30 at Bossekop (Lapland); midnight at Fort Simpson

and on Lake Athabasca; 1.30 A.M. at Point Barrow (Alaska); and finally between 4 and 6 A.M. at Godthaab (Greenland). In general the diurnal variation presents only a single distinct maximum; yet the observations of Palander and Wijkander gave two maxima at Spitzbergen, the one at 10.30 P.M., the other at 4.30 A.M., separated by a minimum at 1.30 in the morning. In the daytime, at 12.30, there was another minimum, much more important, which cannot be attributed to the daylight, as in Spitzbergen the sun remains for two months below the horizon. This double variation appears to be an isolated phenomenon, and is perhaps due to local causes, for the Tegetthof expedition, which wintered among the ice to the south of Franz Josef Land—that is to say, not far from Spitzbergen—recognised only one maximum at about 9 or 10 at night. The hourly distribution of the auroras observed at this station is as follows:

Between 10 A.M. and 2 P.M.	.	.	22 auroras.
" 2 P.M. " 6 P.M.	.	.	58 "
" 6 P.M. " 10 P.M.	.	.	79 "
" 10 P.M. " 2 A.M.	.	.	72 "
" 2 A.M. " 6 A.M.	.	.	40 "
" 6 A.M. " 10 A.M.	.	.	28 "

We have seen in the preceding chapter that the maximum of the absolute frequency of the aurora for the different points of the globe follows an oval zone which has for its centre a point situated between the geographical and the magnetic poles, which we

have named the pole of the aurora. Sophus Tromholt¹ suggested that the diurnal variations which we have just indicated might be explained by a displacement or oscillation of this auroral zone, this oscillation taking place in the course of the twenty-four hours. In the evening, towards 8 o'clock, the auroral zone would, according to this hypothesis, occupy its most southern position; then it would gradually pass towards the north till 8 in the morning, then moving south again, to find itself in its most southern limit at 8 on the following evening. The hour of the maximum for the more southern districts, such as Central Europe, would be that when the auroral zone was most to the south—that is to say, between 8 and 9 o'clock—while at the same moment it would be the hour of the minimum for the regions to the north of the auroral zone, such as Godthaab in Greenland.

This explanation is evidently inspired by that which Weyprecht has proposed to account for the annual period which we shall speak of later. But in the case of the diurnal period it provokes two capital objections; in all the countries which are on the hypothetical course of the auroral zone, in Iceland, at the North Cape, in Nova Zembla, in the south of Greenland, there should be each day two maxima, at the hours when the zone passes the zenith, either when it moves towards the north or in its return towards the south; now to this day the existence of

¹ *Sur les périodes de l'aurore boréale*, Copenhagen, 1832.

two maxima has only been observed in one place, in Spitzbergen, by the Swedish expedition of 1872-73, as we mentioned above. In all the other places situated on the supposed course of the auroral zone there is but one maximum, which is contrary to the hypothesis.

The other objection is that, if the auroral zone effected each day a movement of oscillation, the hour of the maximum should be for all the points situated on the same side of the zone and at the same distance from it at absolutely the same moment, whereas the diurnal variation of the aurora corresponds much more nearly to the local time. Thus the maximum is at 10 o'clock by the local time in Norway as in Canada—that is to say, at moments which are separated from each other by more than six hours of absolute time.

This tendency of the aurora to follow the local time is not less evident when we consider a particular aurora. Thus Donati has pointed out that the great aurora of February 4, 1872, which was seen in both hemispheres, had its maximum everywhere at about the same local time, between 8.30 and 9.30 P.M., and not at the same physical instant, although the difference in the longitude of the stations was more than seven hours.

The hypothesis proposed by Tromholt cannot therefore be admitted, unless with important modifications. If the diurnal variation of the aurora is to be explained by an oscillation of the auroral zone, it

cannot be by any oscillation of the zone as a whole, the entire belt contracting and dilating alternately, all its points approaching or receding from the pole of the aurora. We must suppose not an oscillation, but a progressive alteration in the form of the zone, which should hollow itself, for instance, on one side only, this change in form passing all round the zone in the course of twenty-four hours. It is possible that some such explanation may prove satisfactory. But the data which we possess on the diurnal variation in the frequency of auroras in the Arctic region are not yet sufficiently numerous to permit of a complete solution of the question.

2. *Annual period of the polar aurora.*—The study of the annual period of the aurora presents a special difficulty on account of the great variability of the length of the day in mean latitudes, and especially in high latitudes—that is to say, precisely in the regions where the aurora is most frequent. For it is evident that, other things being equal, the apparent frequency of the aurora will be greater when the night is longer, and conversely. Yet this difficulty is not so great as it would appear at first, inasmuch as the auroras generally last a considerable time, so that the end of an aurora which has begun in the daytime may be perceived after sunset, and especially because the maximum of the diurnal frequency of the aurora is at night.

Mairan was the first to discover the law of the

annual periodicity of the aurora borealis; he remarked that auroras are particularly frequent in France towards the months of April and October—that is to say, soon after the equinoxes—and that they are, on the contrary, rarer in January, and especially in June. The annual period presents thus, in France, two maxima and two minima.

The winter minimum occurs precisely when the nights are longest—that is to say, at the epoch when most auroras would be visible if they were evenly distributed over the year. It must therefore be considered as an undoubted phenomenon, consequent on the nature of the aurora. Nor can it be attributed to a meteorological cause, such as a greater quantity of cloud. For this law of periodicity is general; it is manifest at all the stations of mean latitudes and in both hemispheres; now, in many countries there is not more cloud in December than in March or September.

Mairan's results have been confirmed by all the observations taken in mean latitudes. We will only give as examples the annual variation in frequency of the aurora at Paris, New York, Sweden, and at Hobartstown in the southern hemisphere. In the table given below the numbers for each month indicate the relative frequency of the auroras in hundredths—that is to say, the number of auroras which, out of an annual total of 100, are seen in each month.

It will be seen from this table that the quantity of

cloud has no appreciable influence on the annual period; the principal maximum in Paris is in October, when the aurora is twice as frequent as at the time of the other maximum, in April; yet in this last month there is much less cloud in Paris than in October.

—	Paris	New York	Sweden	Hobartstown
January . .	6	7	11	3
February . .	8	7	12	5
March . . .	8	9	13	8
April . . .	9	11	7	24
May	8	7	1.5	5
June	2	7	0	3
July	5	9	0.5	5
August . . .	8	11	5	0
September .	14	10	13	13
October . . .	18	10	15	21
November . .	8	6	11	3
December . .	6	5	11	10

The numbers, in the case of Hobartstown, result from a less number of years of observation than for the other stations. They clearly show the two maxima of autumn and spring, but it would not be safe to draw any other conclusions from them.

In the three series of the northern hemisphere the two maxima of spring and autumn are very distinct; it will also be remarked that the principal maximum is that of the autumn. This seems to be a general law, due probably to the influence of meteorological conditions on the production of auroras.

The two minima of winter and summer appear also to be unequal; but this inequality is due, in part if not entirely, to the difference of the length of the

nights in the two seasons. Thus the frequency of the auroras, nil in the month of June in Sweden, where there is properly speaking no night, is already sensible in Paris and still greater in New York, where the summer nights are longer than in Paris. Under these conditions it is hard to say whether the two minima are really unequal; it is even possible that the principal minimum is the winter one. The New York series—which is particularly interesting from this point of view, since it seems to indicate that the principal minimum falls in December—comprehends unfortunately a less number of observations than the others, so that it cannot be regarded as giving definite results. Local climatic conditions may also play a part in the relative importance of these two minima; but the existence of two annual minima in mean latitudes is indisputable.

This law of annual periodicity appears to be modified in higher latitudes. The autumn maximum grows later and later, and that of spring earlier, both thus approaching the winter solstice. This fact, noted first by Lovering, has since been verified by numerous observers. It even happens, in sufficiently high latitudes, that the two maxima are fused in one, which falls near the winter solstice. We give in the following table the proportion of auroras observed each month in polar regions, the annual total of auroras being supposed to be 100. The first column results from a comparison of the observations collected

to the north of Baffin Bay by the polar expeditions of Parry, McClintock, Kane, Hayes, and Bessels; we head them 'polar expeditions.' The second is deduced from the observations pursued uninterruptedly by Kleinschmidt at Godthaab in Greenland from 1865 to 1882. This series is the most important of all which are available for these regions, both because of the care bestowed on the records and because of the length of time during which they were prosecuted, and especially because, being entirely due to one person, they are susceptible of strict comparison throughout. We give no number for the four months of May, June, July, and August, since the absence of night during that time permits of no observations of the aurora borealis.

	Polar expeditions					Godthaab
September	.	.	1	.	.	8
October	.	.	6	.	.	14
November	.	.	16	.	.	16
December	.	.	20	.	.	18
January	.	.	24	.	.	17
February	.	.	23	.	.	14
March	.	.	10	.	.	10
April	.	.	0	.	.	8

The Godthaab series is much the best, for the reasons above mentioned, but it will be seen that both are agreed in giving but one maximum; it is in December for Godthaab, in January for the polar expeditions which wintered in the same region, but yet further to the north.

Weyprecht proposes to explain the annual varia-

tions in mean and polar latitudes by a periodic oscillation of the zone of the maximum frequency of the aurora. According to this theory, the zone descends towards the south and recedes northwards again twice a year, occupying its most southern position at the equinoxes and its most northern at the solstices. This hypothesis accounts for the two annual maxima and minima of mean latitudes, and also for the winter maximum of high latitudes. It also points to a second maximum in the latter at the summer solstice; but the complete absence of night at that season prevents the verification of this second consequence of Weyprecht's hypothesis.

This hypothesis has been adopted by many authorities, among others by Tromholt, who even wished, as we have said, to extend it so as to explain the diurnal periodic variation. But latterly it has found an opponent in Paulsen, Director of the Meteorological Institute of Copenhagen. He points out ¹ that the two maxima of the equinoxes and the winter minimum are observed at St. Petersburg, Abo, Stockholm, and Christiania, whereas at Hammerfest, in the north of Norway, there is but one maximum, at the winter solstice. This latter station should therefore, according to the hypothesis, lie at all seasons to the north of the zone of the maximum frequency of the aurora, and this is contrary to

¹ 'Contribution à notre Connaissance de l'Aurore boréale' (*Bulletin de l'Académie royale danoise des Sciences et des Lettres*, 1889).

known fact. Paulsen remarks, in addition, that to explain the difference in the annual variation of mean and high latitudes there is no need to suppose a displacement of the zone of maximum frequency. It is enough to assume that a more active production of the phenomena of the aurora borealis in mean latitudes involves thereby a slackening of activity in the zone proper to the aurora. This hypothesis is an extremely probable explanation of the facts ; it agrees completely, as we shall see later, with the theory of Edlund. This theory explains the aurora by a flow of electricity from the equator towards the poles ; now, it is clear that if a greater part of this flow is manifest at a given moment in mean latitudes there will be less for the polar regions. Finally, direct observation seems to justify this view ; Kleinschmidt has shown that auroras were either non-existent or very faint at Godthaab at seasons when great auroras were seen in low latitudes.

Thus, to sum up the argument, if in high latitudes more auroras are seen in winter than at other seasons, this is due merely to the fact that there are at that time fewer manifestations of the aurora in mean latitudes than at the equinoxes. The zone of the maximum frequency of the aurora remains at the same invariable position, or nearly so ; only auroras are a little less numerous in this zone when they are more numerous in lower latitudes. It only remains to explain why the annual period of the aurora

presents two maxima, at the equinoxes, in mean latitudes.

3. *Secular period of the aurora borealis: relation of the aurora with the spots on the sun.*—

The study of the period of the aurora, embracing several years, presents great difficulties on account of the lack of regular observations which may be compared together and extending over a sufficient space of time. Every time that, in a given country, there is a change of observer, we remark a sudden variation in the annual number of auroras. It is necessary, therefore, as far as possible to collect the observations over a whole region, and not content ourselves with a single station, for it often happens that in two neighbouring places an aurora will be noted in the one which is unperceived at the other by a less attentive observer. At the present day, with the multiplication of observatories, it is hardly possible for an aurora to escape notice, unless the state of the weather is absolutely unfavourable. Recent catalogues are then complete, or nearly so; but this is not the case with regard to those of a century or two back. We have to search for the chance mention of auroras in the pages of historians; and even so we only attain to very incomplete lists, which include only auroras of exceptional intensity. At still earlier dates the descriptions of chroniclers are couched in such ambiguous terms that it is often impossible to tell whether they relate to an aurora, a meteor, or a comet. In spite of

these difficulties, it has been established that the appearances of the aurora borealis are periodic, and these longer periods are the more interesting that they seem to coincide with those recognised in the case of other phenomena, such as terrestrial magnetism and the spots on the sun. The question of the secular variations of the aurora demands, therefore, a detailed study.

The idea of periodicity in the returns of the aurora borealis occurred to Mairan. Although he had not determined the length of the period, he mentions all the occasions of the renewal of the aurora—that is to say, of the maxima of frequency—of which he could find the trace as far back as classic times, by consulting historians and chroniclers. He even goes further and asks whether it would not be possible to establish some analogy between the frequency, the cessation, and the return of the spots on the sun and the manifestations of the aurora borealis.¹ ‘This idea is encouraged,’ he adds, ‘by the fact that during these last five or six years, when the aurora borealis has been so frequent, so also have been the spots on the sun. It is known that at the beginning of the last century, after the invention of the telescope, the sun was hardly ever seen without spots; and there were at times such numbers of them that P. Scheiner said that he once counted as many as fifty. They afterwards became more rare, so that from the middle of the century until 1670—that is to say, for twenty

¹ Mairan, *Traité de l'Aurore boréale*, 1st edition, 1733, p. 250.

years—only one or two were seen, and these only for a short time. Now, as we have seen, there was a great number of auroras at the beginning of the seventeenth century and till after 1621, after which date we hear no more of them till 1686.'

After Mairan many authors have discussed this question, and proposed to explain the returns of the aurora by different periods. Hansteen believed that the period was ninety-five years on an average; Denison Olmsted gives a period of sixty-five years divided into two parts, the one of twenty-five years, during which the auroras are numerous, the other of forty years, during which the cause which produces the auroras is in repose. But none of these tentatives have led to any satisfactory results until there was a return to Mairan's idea of a relation between the spots on the sun and the aurora borealis.

It is known that the periodicity of the sun spots, divined by Fabricius in 1610, was definitely proved by Schwabe in 1826, whose studies were amplified and confirmed by a great number of observers and men of science, among whom we may mention Warren de la Rue, Carrington, Secchi, Spoerer, and especially Rudolf Wolf, of Zurich. According to the latter, the spots on the sun observe a period of a little more than eleven years (eleven years and two months exactly) composed of two unequal parts; there are, on an average, six years between the maximum and the minimum which succeeds it, and five years between

the latter and the next maximum. The period of increase is thus shorter than the period of decrease.

These facts relating to the sun spots are perfectly certain at the present day. The periods are not all precisely equal, being sometimes a little longer or shorter ; but they never fail to manifest themselves, and there is always an enormous difference between the number of spots which corresponds to a year of maximum and that of a year of minimum.

In the following table we give, from the researches of R. Wolf and from a summary of these which has been recently published by M. A. Wolfer,¹ the epochs of the maxima and minima of the spots on the sun since 1610. We add to these after 1700 the relative numbers of the sun spots during the year under consideration. These numbers are obtained according to the method suggested by R. Wolf, by counting simply the number of isolated spots, and adding them together ; adding to these the sum of the numbers of groups of spots, each group being reckoned as equivalent to ten spots. We indicate only in round numbers the years of maxima and minima, neglecting fractions of a year. These are, indeed, still uncertain to the extent of a few months ; in earlier centuries the uncertainty may amount to a year or two.

The periodicity of the solar spots which is set forth in the above table is a most marked phenomenon :

¹ *Bibliothèque universelle de Genève*. 'Archives des Sciences physiques et naturelles,' vol. xxvi. 1891, N°. 12.

*Epochs of the maxima and minima of the spots on the sun.
Relative number of the spots, after 1700.*

Minima	Maxima	Relative numbers	Minima	Maxima	Relative numbers
1610		—		1761	86
	1615	—	1766		11
1619		—		1769	106
	1626	—	1775		7
1634		—		1778	154
	1639	—	1784		10
1645		—		1787	132
	1649	—	1798		4
1655		—		1804	73
	1660	—	1810		0
1666		—		1816	46
	1675	—	1823		2
1679		—		1830	71
	1685	—	1833		8
1689		—		1837	138
	1693	—	1843		11
1698		—		1848	124
	1705	49	1856		4
1712		0		1860	96
	1718	51	1867		7
1723		10		1870	139
	1727	90	1878		3
1733		5		1883	64
	1730	83	1889		6
1744		5			
	1750	83			
1755		10			

the relative number of spots is only six on an average at the time of the minima; it is ninety-three (or fifteen times as many) at the time of the maxima.

In 1852 Sabine, Wolf, and Gauthier announced almost simultaneously that the variations of magnetic declension were also subject to regular periodicity, and that their period corresponded exactly with that of the sun spots. This coincidence, which is now perfectly recognised, became the point of departure

for a series of analogous researches, and soon men sought to establish relations between the spots on the sun and all meteorological phenomena. This was carrying things too far, and relations which were wholly illusory were the result; nevertheless, some curious and genuine results were attained, among which may be reckoned those which concern the aurora borealis. Suggested, after Mairan, by Stevenson, J. A. Brown, R. Wolf, Secchi, and Hansteen, the relation between the aurora borealis and the sun spots was studied and finally proved by Fritz, Loomis, and Lovering. Fritz appears to have been the first who distinctly laid down the law that the number and importance of the auroras follow exactly the same variation as the spots on the sun, so that the epochs of the maxima and minima coincide almost exactly for the two orders of phenomena.

Among the epochs of the maxima of the aurora borealis we may mention in especial the years 1615, 1686-87, 1707, and 1728, which are indicated by Mairan, and correspond fairly exactly with the maxima of the sun spots, as may be seen from the preceding table. In our own century the same coincidence is shown principally in the years 1804, 1810, 1830, 1848, and finally in the winters of 1859-60 and 1870-71, in which we have more than once mentioned numerous and exceptionally extensive auroras.

Yet if the agreement appears to be sufficiently satisfactory as a general rule, it must not be denied

that there are considerable discrepancies in detail, as will be seen from the diagram (fig. 17), which represents by the lower curve the variation of the sun spots (relative numbers) from 1720 to 1875, and, for the same period, by the upper curve, the number of auroras seen each year in Central Europe, between the latitudes 46° and 55° , according to Fritz's catalogue.

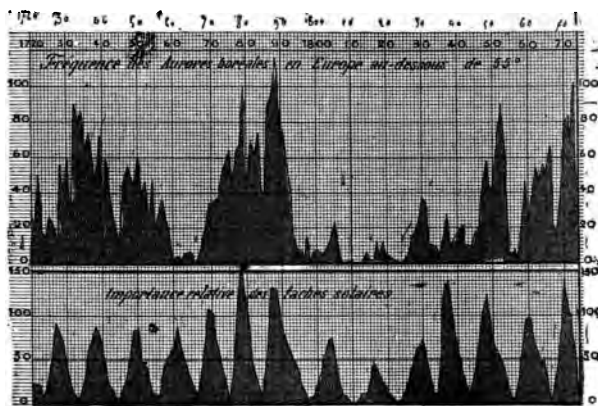


FIG. 17.—COMPARISON OF THE FREQUENCY OF THE AURORA WITH THE SPOTS ON THE SUN.

The line of the frequency of the aurora is far less regular than the other; it is wanting in continuity, and presents abrupt transitions. Certain maxima of sun spots do not correspond to a maximum of auroras, for instance, in 1761; conversely, as in 1732, 1733, and 1734, there is a maximum of auroras where there is a minimum of sun spots. Finally, the epochs of

the maxima and of the minima of the auroras outrun or lag behind, in an irregular manner, the corresponding epochs of the period of the sun spots.

These discrepancies may be partly due to the fact that the auroras have not been sufficiently observed. In order to be sure that none escape observation regular watch should be kept in countries situated in longitudes sufficiently far apart, so that it should always be night in one or other: for instances, in Central Europe, in the United States, and in the north of China. It would also be desirable to have similar stations in high latitudes; but these observations should be considered separately from those of mean latitudes.

For, according to the researches of Tromholt, based on the observations of the aurora borealis collected in Greenland, it would seem that in that country the relation which we have indicated as existing between the aurora and the spots on the sun is reversed: the maximum of auroras being manifest during the minimum of sun spots, and inversely, that is to say exactly the opposite of what is observed in mean latitudes. Tromholt explains this contrast between Greenland and mean latitudes as he had already explained the diurnal period, by supposing that the auroral zone executes, during the period of the sun spots—i.e. in a little more than eleven years—a movement of oscillation from the north to the south and conversely. We have already set

forth, in our study of the annual variation of the aurora, the objections which may be made to this theory of an oscillation of the auroral zone, and we have indicated a simpler and more natural explanation, proposed by Paulsen. This explanation accounts perfectly for the antagonism apparent between the two regions, whether in the annual variation or any other period. However this may be, this difference may certainly be invoked as one of the causes which tend to disturb the parallelism between the period of the aurora and the spots on the sun. For if the maximum of the auroras corresponds, in mean latitudes, to the maximum of the solar spots and to the minimum in the arctic regions, it is clear that there must be between these two an intermediary zone, in which the law of periodicity is undetermined, and may be inappreciable or even quite different. Now this zone is precisely that in which auroras are most frequent; if then we consider together and without distinction the auroras of the opposing regions, or even those only of the intermediate zone, it will be easily understood that the law of periodicity is no longer very obvious.

Another disturbing cause, on which we have already more than once insisted, is that we include under the common designation of aurora borealis phenomena which appear to be distinct both in their producing cause and in their form and extent. If a first class of auroras, peculiar to high latitudes, is of purely terrestrial and even local origin, while another

class depends more particularly on the yet unknown cause which produces also the variations in the spots on the sun, it becomes quite natural that the relation of the sun spots with this second class of auroras should be obscured in part by the confusion between the two sorts of aurora. It is, therefore, desirable to reckon apart henceforward the auroras which are produced over a wide extent of country and which are accompanied by general magnetic disturbances, and those which, on the contrary, have rather a local character, and coincide with no abnormal movements of the magnetic needle in mean latitudes. It seems to us probable that the general auroras of the second class, considered alone, would show a periodic variation much more closely in agreement with that of the spots on the sun than has hitherto been established.

We have considered at some length the period of eleven years shown by the aurora borealis. It is in truth the most obvious and the one which is most easily recognised. But there are besides other periods, both longer and shorter. Wolf discovered in the alternatives of the sun spots a period of about fifty-five years and a half, comprehending nearly five of the periods of eleven years. The superposition of these two periods results in the accentuation and weakening alternatively of certain maxima and minima of the undecimal period. Thus the maxima of the sun spots were particularly marked in 1778 and 1787, and in

1837 and 1848, while the intermediate maxima, and especially that of 1816, were relatively weak.

An analogous period is manifest also in the auroras. The most important maxima which have been noted in Europe are those of 1788 and 1848, which correspond nearly to the period under consideration, and coincide with the great maxima of the spots on the sun. Lastly, as in the case of the spots on the sun, the maximum of 1817 was very weak.

Beside these coincidences we must set cases of marked divergence. Thus the maximum of 1870, which was remarkable both for its auroras as for the sun spots, does not appear to enter into the period we are considering. The duration of this period, estimated at fifty-five and a half years, cannot, however, be considered as exactly known; the interval of time covered by the observations is not yet long enough to furnish sufficient elements for calculation.

Besides these long periods, other and much shorter ones have been noted; it would seem easy to determine these with great exactitude; but the amount of the variation corresponding to these shorter periods is much slighter, and this renders the periods less distinct. It is known that the sun spots are subject to a period of a little more than twenty-seven days, corresponding to the apparent rotation of the sun, or at least to that of the spots. It would seem that there exists in the frequency of the auroras an identical or

very similar period. In any case great auroras are frequently seen at intervals of 28 or 30 days ; we give some examples of these coincidences :

October 17, November 17, 1818.	Interval 31 days.
January 19, February 19, 1852.	" 31 "
September 1, October 1, 1859.	" 30 "
October 14, November 19, 1865.	" 31 "
October 22, November 14, 1868.	" 28 "
April 15, May 14, 1869.	" 29 "
January 3, February 1, 1870.	" 29 "
September 21, October 34, 1870.	" 30 "

An analysis of the epochs of the recurrence of auroras between September 22, 1846, and February 4, 1872, gives Fritz a period of 27 days, 7 hrs., equivalent consequently to that of the spots on the sun. Veeder,¹ studying the records of observations taken in the United States, finds a period of twenty-seven and a quarter days. He thinks, moreover, that he may venture to assert that every time that an aurora is seen there is a group of spots on the eastern border of the sun. According to him there is no exception to this rule, and auroras are only to be seen when such groups of spots are on the eastern border of the sun to the exclusion of every other position. The converse does not hold ; though auroras always coincide with the appearance of spots on the eastern border of the sun, sun spots may exist in that position without any corresponding manifestation of auroras ; but, in the latter case, the place of the aurora would be taken

¹ *Proceedings of the Rochester Academy of Science*, vol. ii., Rochester, 1893, and *American Meteorological Journal*, vol. ix., p. 105, June 1893.

by storms. This substitution of storms for auroras, if established, would be a very remarkable fact, and of the greatest importance to the theory of the phenomenon. On the other hand, some observers think that the aurora borealis and magnetic disturbances coincide with the passage of the spots over the central meridian of the sun, and not with their appearance on its eastern edge. There is, moreover, a distinction to be established between the quiet spots and those which present an appearance of violent eruption, easily recognised by the spectroscope; the latter only are in relation with the aurora borealis. It is to be desired that further researches, carried on in different countries, should be brought to bear on the laws enunciated by Veeder.

To conclude: it results from all that precedes that the aurora borealis, in spite of its apparent irregularity, observes well-established periods—for instance, the diurnal period, the annual period, and the period of a little more than eleven years. Among the periods of which the duration is less exactly known, but of which the existence seems to be proved, there is one of about twenty-eight days and another of about fifty-five and a half years. Others have been surmised, especially one of 220 years, but they are extremely doubtful, and we will not stay to consider them.

CHAPTER VI.

OF THE AURORA RELATIONS WITH METEOROLOGICAL
PHENOMENA.

1. *Relation of the aurora with the weather.*—Some link has been sought for a long time between the polar aurora and various meteorological conditions, the height of the barometer, rainfall, wind, &c. ; but hitherto only negative or contradictory results have been arrived at. Whereas in Labrador, for instance, coloured auroras foretold fine weather, in Greenland, at no great distance, they seemed to herald the south wind and storms ; this was in particular the opinion of Scoresby. Hansteen concluded from his long series of observations, that at Christiania the aurora borealis was nearly always followed by a lowering of the temperature ; but on the other hand, Argelander says that at Abo and at Helsingfors the barometer fell and the temperature rose during the auroras. In short, it would not be difficult to give many similar pairs of contrasting opinions on the relations which may exist between the aurora borealis and the weather, even in neighbouring districts. And most authorities now admit that there is no connection between the

aurora and the different aspects of the weather, and that the two orders of phenomena are entirely independent.

Yet this independence is perhaps more apparent than real, and these contradictory conclusions are perhaps due to the fact that the problem is badly stated. First of all, it is evident that there is no possible relation between the weather and the great auroras which are seen at one and the same time over nearly the whole surface of the earth ; we must begin then by eliminating all these great auroras, and consider only the local auroras, which are especially frequent in high latitudes. It is necessary to remark, further, that so long as meteorological science was content to study isolated phenomena, in each locality separately, apparently contradictory results were also attained : in one country, the south wind caused a fall in the barometer ; in another, though at but little distance, it was the north or west wind that produced this effect, and so on. In order to draw any conclusion from facts which were in such apparent contradiction, it was necessary to consider not only what happens at a given point, but the simultaneous variations of the various meteorological elements and their distribution over a wide extent of country. For instance, the connection between the movements of the barometer and the direction of the wind only became intelligible when charts, showing the distribution of pressure and the direction of the wind

at a given moment over the whole of Europe, were obtainable.

If there be any relation between the manifestations of a certain class of auroras (we have said above that there can be no such relation in the case of the great auroras) and any meteorological phenomena, this relation will certainly be discovered by analogous means, by studying the general distribution of pressure, of the temperature, of humidity, and of the winds over a great part of the northern hemisphere, at the time of the production of the aurora. The only attempt which has hitherto been made in this direction is that of Forsman, who arrived at the following conclusions :

The variations in the barometer are generally opposed in the two parts of Europe which are separated by a line passing from the north of Scotland to the Black Sea. Now when auroras are observed in Sweden the barometer rises, that is, there is already a maximum of pressure in that part of Europe situated to the north-east of the above mentioned line ; the barometer falls on the other hand, i.e. there is a minimum of pressure, in the south-western part. These results need to be confirmed and extended by further research ; they serve at any rate to show the direction which study should take.

In the Arctic seas, which are alternately frozen in winter and free in summer, the aurora seems to

follow the limit of the ice. This fact, to which Bravais first drew attention in Lapland, has since been confirmed by Weyprecht in Franz Josef Land, by the various Swedish expeditions to Spitzbergen, and more recently, in 1882-83, by the Austrian Polar expedition to Jan Mayen Island. This is an evident proof that the production of the aurora borealis may be influenced by certain meteorological conditions

Independently of the relations which may exist between the appearance of the aurora and the particular state of the atmosphere, there are certainly other relations between this state and the form under which the aurora manifests itself; it would seem that certain forms of the aurora are more commonly seen in particular countries, and are consequently in relation with the climatic and topographical conditions of the locality. The laws of the geographical distribution of the different forms of auroras need therefore special study, and it is probable that the results of such study would have an important bearing on the theory of the phenomenon. There are at present few data on this head.

In the north of Behring Strait, where the 'Vega' wintered, the aurora constantly presented the form of an homogeneous arc, while the radiated forms were extremely rare; during the whole winter only one aurora in the form of drapery was seen. Is this predominance of the auroras of the third type a

geographical fact, or does it depend solely on the particular characteristics of the winter of 1878-79? This question can only be solved by further observations taken at another epoch in the same region, and if possible at another phase of the undecimal period, for it is also possible that the general form of the aurora is not the same at the moments of the maxima and minima.

We have somewhat more precise data on the draped auroras. With very rare exceptions, notably an aurora in the form of drapery seen in Paris on the night of April 15-16, 1869,¹ this form of aurora has been observed only in districts near the seas which in winter remain open and free from ice. The countries where these auroras have been chiefly seen are the north of Norway, Nova Zembla, Franz Josef Land, Spitzbergen, the eastern coast of Greenland, and Newfoundland. It may be noticed that these countries are all in the neighbourhood of the barometric minimum, which obtains as a rule in winter in the North Atlantic. This coincidence merits attention.

2. *Relation of the aurora with the clouds.*—Clouds constitute the meteorological phenomenon which offers the clearest and least disputable relation with the aurora borealis. We have already mentioned (page 15) the close resemblance which obtains

¹ We reproduce (fig. 18) the appearance of this aurora, from the drawing of Silbermann.

between certain forms of the aurora and the clouds which are known as cirro-stratus and cirro-cumulus, a resemblance so close that it is often difficult to judge whether a given effect is due to real auroral lights, or to clouds lit up by some reflected light. We also remind our readers that we have mentioned several cases in which a halo produced by the refraction of the light of the moon through the ice needles which constitute the cirrus, has been observed at the same time as an aurora.

Sometimes these clouds are stretched out in long parallel lines, which, by the effect of perspective, seem to converge upon two opposite points of the sky. These bands of cirrus are, as a rule, in one or other of two directions. Sometimes they are sensibly parallel to the needle of the compass, and lie consequently north and south, within a degree or two; they are then known as polar bands. At other times, on the contrary, they take a direction perpendicular to the preceding. In the first case they are oriented like the isolated rays of the aurora; in the second they recall the form and the disposition of the arcs.

At Bossekop the French Commission had occasion to observe especially the cirrus clouds directed perpendicularly to the magnetic meridian, that is to say, in the direction of the auroral arcs. The mean orientation of these bands of cloud, deduced from twenty-four distinct observations, was E. 28° N.—W. 28° S., while the mean orientation of the arcs of the

aurora was E. 21° N.—W. 21° S. The difference is only seven degrees, which is very little, especially when we consider the difficulty of such measurements and the irregularities which are not uncommon in phenomena of this nature. It is therefore legitimate to assume with Bravais that the cause, whatever it may be which determines the orientation of these bands of cloud, is also that which regulates the position of the auroral arcs.

Not only have these bands of cloud a close analogy in form and position with certain polar auroras, but as we have already indicated there seems often to be the closest connection between the two phenomena. Sometimes, when the aurora borealis disappears in the morning before the light of day, its place is taken in the sky by bands of cirrus; more often still, these clouds are first seen in the daytime, and the following night the rays, or the arc, of the aurora replace them.

Since Frobesius, who was the first to indicate some of these relations in 1739, a great number of observers have given numerous and curious examples of the analogies of the aurora with clouds. Hell, in 1769, notices that these bands of cloud are, like the aurora, much more common in the arctic regions than in mean latitudes; he also signalised the apparent transformation of the aurora of the night into the cloudy band of the day, and *vice versa*. Weber and H. Fritz also remarked that every time that they observed polar bands of cloud during

the day there was an aurora the following night. Winnecke considered the analogy so complete that he does not hesitate to regard these clouds as the vehicle of the auroral lights.

After prolonged study of the subject Weyprecht arrives at the same conclusion. In his opinion the luminous phenomena of the aurora are such that the light seems to be intimately connected with material particles. Wherever two or more rays cross, the intensity of the light augments; and this is also the case where an auroral band seems to make a fold; moreover, the wind seems to act upon the aurora, which appears torn after a tempest; finally, the presence of clouds seems to favour the development of auroras.

A last relation between cirrus clouds and the aurora results from the fact that the annual variation in the frequency of the aurora sensibly follows the same course as that of halos. Tycho Brahé observed this parallel march of the two phenomena, which presented maxima simultaneously in 1580 and in 1590, years which must themselves be very near those of the maxima of sun spots.

Hermann J. Klein, comparing twenty-five years of observations made with the greatest care at Cologne by Dr. Garthe, has shown that cirrus, cirro-stratus, and cirro-cumulus, that is to say the highest clouds, follow, as to their frequency, the same laws as the spots on the sun. They presented minima in

1856-57 and 1865-66, and maxima in 1850, 1858-1859, and 1870; now the years of the minima of sun spots are 1856 and 1857, and those of maxima 1848, 1860, and 1870. The agreement is thus as satisfactory as possible; the amount of variation is moreover important; the mean annual frequency of the cirrus in the years of minima is about 95, while it rises to 140 in years of maxima.

Tromholt attains similar results from a comparison of the frequency of auroras and that of halos. In the seventeen years 1857-73 the numbers were as follows:—

—	Halos	Auroras	—	Halos	Auroras
1857	7	2	1866	29	13
1858	15	5	1867	18	7
1859	27	13	1868	18	5
1860	24	7	1869	24	17
1861	20	11	1870	28	22
1862	16	9	1871	47	22
1863	19	4	1872	32	18
1864	9	4	1873	36	15
1865	42	18			

The parallelism of the two series appears to be complete, especially when we consider the difficulty of these observations, which may be entirely suspended during long periods of bad weather.

To conclude: an undoubted relation exists between certain clouds of the cirrus class and the aurora borealis; the two phenomena are subject to the same laws of periodicity, succeed each other, or even coexist, their analogy being often so close that many observers

are of opinion that the appearance of the aurora depends on the presence of these clouds. We shall see that these facts are of great importance to the theory of the aurora.

3. *Relation of the aurora with the electricity of the atmosphere.*—It occasionally happens that certain electric manifestations occur near the surface of the earth at the same time as an aurora borealis. Thus Brewster once observed the fire of St. Elmo on the steeple of a church during an aurora. Hildebrandsson also reports that Oscar II., King of Sweden, saw in his youth, when navigating in high latitudes of the Arctic seas, the fire of St. Elmo during a great aurora borealis, though there was no other sign of storm. Lastly, the ships 'Webfoot' and 'Southern Cross,' which doubled Cape Horn on September 1, 1859, observed the great aurora australis, of which we have more than once spoken, and which was visible simultaneously in the two hemispheres; a violent storm then prevailed, and balls of fire were seen at the extremities of the masts and yards of the vessels.

These three cases are perhaps the only ones known in which any manifestation of electricity was produced near the earth during the aurora borealis. All other observations made in the most different countries and under the most varied conditions never give anything but negative results.

As early as 1770 Van Swinden had remarked that

atmospheric electricity did not appear to vary during the prevalence of an aurora. In his various voyages to the Arctic regions, from 1819 to 1825, Parry made frequent experiments with a metal point carried on a mast 85 feet high, which was placed in communication with a sensitive electrometer. He never obtained any electricity during the auroras. Scoresby, Sir John Franklin, McClintock, Nares, &c. arrived at similar negative results, as also did Poey, who observed at Havana during the great auroras of August 26 and September 27, 1859, and Secchi, who caused observations to be taken in several parts of Italy during the auroras of October 24 and 25, 1870.

Recent observations made with perfected apparatus of the most sensitive description have not given better results. During a period of magnetic disturbances which was observed at Paris, from April 13-20, 1882, during the whole of which there were auroras on the Atlantic, although none were noticed in Central Europe, the register of atmospheric electricity at Paris indicated, according to Mascart, no perturbation which could be connected with the magnetic phenomena. This was also the case on October 2 of the same year, when a brilliant aurora was seen all over Central Europe, even to the shores of the Adriatic.

Among all the missions which took part in the International Polar Expeditions of 1882-83, the Swedish mission which sojourned at Cape Thorsden (Spitzbergen) is the only one which, in the northern

hemisphere, made regular observations of the atmospheric electricity. These observations were prosecuted by Andrée, by means of a Mascart electrometer. Andrée found that before the appearance of an aurora the positive electric potential of the air diminishes abruptly, and even becomes negative, as usually happens when it rains. As soon as the aurora appears the potential takes, as before, a high positive value. The single case of negative electricity observed in a clear sky (December 1, 1882) was followed a few minutes later by an aurora borealis.

But it must be noted that the electric potential of the air, especially at a short distance from the surface of the earth, varies constantly in so abrupt and irregular a manner that it would be imprudent to assume any coincidence, even though these variations are observed during an aurora, since they are always happening. Sometimes at a station, where the sky remains clear, distant rains produce a negative potential, of which the cause would be unknown, if we had not the total of the meteorological observations over a vast region. Finally, the variations of the potential in two neighbouring stations often offer no resemblance. It would therefore be rash to assume a relation between auroras and the electricity of the atmosphere from a small number of observations gathered in a single station; such a relation could only be considered as proved, if it were proved by repeated observations from different stations that a

perfect simultaneity exists between the variations of the potential of the air and the different phases of the aurora.

The recent experiments of Lemstroem in the attempt to produce artificially the effects of the aurora borealis bear on this question. These experiments, begun in 1871, have been prosecuted especially in Finnish Lapland in the neighbourhood of Sodankyla and Kultala, during the winters of 1882-83 and 1883-84.

At the summit of the hill Kommattiwaara, which attains a height of 426 feet, near Sodyanka, Lemstroem disposed an electric apparatus composed of a wire, bearing upright points at every twenty inches. This wire, of which the points were turned towards the sky, was arranged in an immense spiral square, covering a total surface of 435 square yards, each turn of the spiral being separated from the next by a distance of five feet. The whole was supported on posts eight feet four inches high, furnished with sulphuric acid insulators. Lastly, the end of the wire, also insulated, was carried to the observatory at the foot of the hill, and terminated in a disc of amalgamated zinc sunk in a neighbouring stream. Other similar apparatus, but of smaller dimensions, were placed experimentally at other points. In these conditions a galvanometer situated on the course of the wire indicated an electric current directed from the ground towards the atmosphere, when the apparatus was at a short distance

above the surface of the ground. When, on the contrary, the height was increased to a few yards a current was observed to pass from the atmosphere towards the ground. If two such apparatus are disposed at different heights, the lowest being raised at least nine or ten feet, and a galvanometer is placed on the wire which connects them, the galvanometer is traversed by a current which passes from the higher of the two apparatus to the other.

Above these apparatus were seen several times luminous phenomena, sometimes in the form of diffused lights, sometimes, but rarely, in the form of rays which seemed to dart from the points of the wire towards the sky. This light showed in the spectroscope the characteristic greenish-yellow line of the aurora, whereas this ray was not visible in other parts of the sky. It even occurred that the line was visible above the apparatus when the eye could not distinguish any luminous appearance. A Holtz machine, put in action in the conductor, reinforces the luminous phenomena if it already exists, and may even provoke it if the circumstances are favourable. Lastly, Lemstroem observed three times, but only twice with absolute certainty, a luminous ray, analogous to an auroral ray, which started from the apparatus and gave the greenish-yellow line in the spectrum. Once this ray appeared during an aurora borealis in the form of an arc.

Lemstroem considers these experiments very

important to the theory of the aurora borealis. They have provoked much criticism, notably from Tromholt, who had installed a similar apparatus in Iceland and obtained no results. It seems to us, however, that we must admit the results obtained by Lemstroem, who conducted his experiments with great care and method. Yet their bearing is limited by the fact that they have hitherto only succeeded with himself, and in the particular locality where he prosecuted them. Vausenat, the founder and first director of the observatory of the Pic du Midi, installed in 1884, at the summit of the Pic du Midi, at an altitude of 12,440 feet, an apparatus similar to that of Lemstroem, but of yet larger dimensions. It was composed of a cable of galvanised steel wire, armed with ten or twelve very sharp points to the yard. The cable was carried on 200 posts ten feet high, and covered a total surface of 765 square yards, above which were 14,000 points.

During the ten months that this apparatus remained *in situ*, a luminous ray was never once seen, nor even St. Elmo's fire, which constantly illuminates the lightning conductors of the observatory during storms.¹ The sole result was to produce in the neighbourhood of the wire violent electric discharges, which caused serious danger to the observers, the cables which put the suspended wire in communication with the earth being at

¹ St. Elmo's fire is very common at the Pic du Midi on the lightning conductors; at times, as I have seen myself, when the hand is raised in the air, the ends of the fingers are tipped with luminous balls, accompanied by the characteristic sound.

times insufficient to discharge the electricity which accumulated on the network of points. Once, when near the apparatus, Vaussenat had his eyebrows and eyelashes burnt, the skin of his face was scorched, his clothes singed, and the spring of his watch affected. On the same day and the following days sparks, passing along the communicating wire between the apparatus and the laboratory, struck several persons. It therefore became necessary to cut the communication and to interrupt the experiment. Vaussenat was convinced as a result of these attempts that the luminous effects observed by Lemstroem were none other than fires of St. Elmo. This conclusion appears indeed to be the most probable one. As to the current observed by Lemstroem to flow between the two apparatus placed at different heights, it does not appear to constitute a new phenomenon. The potential is known to be greater as we rise in the air; two such apparatus, therefore, placed at different heights, will always, if there is sufficient electricity, manifest in the wire which connects them a current from the higher to the lower. This is an entirely natural phenomenon, and in no sense implies the presence of electric currents in the atmosphere, but only that of a static potential, increasing with the height. In any case new experiments are necessary to prove the existence of electric currents in the atmosphere, and the relation which Lemstroem has imagined between these phenomena and the polar aurora.

CHAPTER VII.

THE AURORA RELATIONS WITH TERRESTRIAL MAGNETISM,
ETC., AND TELLURIC CURRENTS.

THE relations of the aurora borealis with terrestrial magnetism are of two kinds: in the first place, the auroras seem to depend, for their form and position in space, on the general distribution of magnetism on the surface of the globe, and especially on the mean values of the declension and inclination at each point. In the second place, the appearances of the aurora coincide, in a great number of cases, with the disturbances which affect from time to time the various elements of magnetism. We will examine successively these two orders of relations.

1. *Relation of the aurora with the general distribution of terrestrial magnetism.*—We have more than once mentioned the fact that the auroras in the form of an arc are generally so oriented that their summit is near the magnetic meridian. Thus, in France and in the greater part of Europe, when an auroral arc is seen in the northern quarter of the sky, its summit is generally between the north and the north-west; it lies, on the contrary,

between south and south-east if the aurora appears on the other side of the zenith, which is, moreover, much more rare. The rays, whether isolated or collected into an arc, a crown, or drapery, are nearly parallel to the magnetic needle, so that, according to the laws of perspective, the point on which these rays seem to converge in the heaven is near the magnetic zenith. The force which governs the auroras appears therefore to be the same as that which the magnetic needle obeys.

Yet this dependence is far from being absolute. The observations of Argelander at Abo between 1823 and 1831 had already shown that, in that locality, the summit of the arcs of the aurora is on an average ten degrees to the west of the magnetic meridian. The French Commission at Bossekop arrived at a similar conclusion : the 226 arcs which were observed and measured at that station during the winter of 1838-1839 had a mean position of eleven degrees west at the summit. But individual cases show a considerable deviation ; 36 per cent. of the observations gave for the azimuth of the summit a distance of more than 30° west of the magnetic meridian, and the extreme variations between the azimuth of the summit are 36° to the east and 90° west. Moreover, if the 226 arcs are classed according to their height above the horizon, it is found that their azimuth varies almost regularly according to the height of the arc ; thus the summit of those arcs of which the height is less than thirty

degrees have only a mean deviation of 6° from the magnetic meridian, whereas the summit of those which pass the zenith, and appear in the southern half of the sky, has a mean deviation of 13° .

Bravais attempts to explain these variations by supposing that the magnetic declension is not constant at different degrees of altitude, but that it increases with the distance from the surface of the earth. In his opinion this hypothesis is the more probable that in the whole of the north of Europe the direction of the magnetic meridians presents a marked deviation towards the east; it may thence be supposed that this deviation is caused by local causes, of which the influence becomes less and less sensible with the altitude above the ground, and thus a progressive increase of the declension becomes apparent at greater altitudes. Where the aurora is produced at a height of 150 kilometres (93 miles) an increase of one degree in 14 kilometres ($8\frac{1}{2}$ miles) would explain the mean deviation of eleven degrees to the west of the magnetic meridian manifested by the auroral arcs.

This hypothesis involves consequences which render it very difficult of acceptance. For, as we have said, the deviation of the summit of the arcs with regard to the magnetic meridian increases with the angular height of these arcs. To explain this variation it would therefore be necessary to suppose in addition that the absolute height of the arcs increases with their angular height; now this new hypothesis

would give for those arcs of which the summit is on the southern half of the horizon so great an absolute height that these arcs must have been visible in the centre and even in the south of Europe, which was not the case.

Retaining the first hypothesis (increase of magnetic declension with the altitude) we might, to replace the second (increase of the absolute height of the arcs with their angular height), suppose that the polar aurora is at a less altitude in the atmosphere over the sea than over the continent. At Bossekop, as a consequence of the relative positions of the sea and land, the arc would be less high in its eastern half than at the other, and thus asymmetrical. Starting from the zenith the apparent summit of the arcs would then be deviated more and more towards the east in the degree that the arcs were at a less height above the horizon, towards the north as towards the south. The summits of the arcs would thus be nearer the magnetic meridian in the northern half of the heaven, and further from it in the southern half, which appears to agree with the observations. We must add, however, that this explanation would not apply in the case of other countries, Spitzbergen for example, where, however, the mean deviation of the summit of the arcs is the same as at Bossekop.

In conclusion, Bravais thinks that all these causes act simultaneously, and that they co-operate in producing the observed deviations. But none of

these hypotheses can be verified, even indirectly, and, if they offer an approximate explanation of the mean deviation of the auroral arcs at different heights, they are entirely insufficient to account for the considerable deviations which are observed when, instead of considering the average, each aurora is studied separately. Thus on January 16, 1839, Bravais observed an arc of which the summit was 90° to the west of the magnetic meridian ; and on January 21 another arc had its summit 36° to the east of the same meridian.

Observations taken in other regions have also shown that the azimuth of the summit of the arcs does not as a rule coincide with the magnetic meridian. Thus Nordenskiöld, during the wintering of the 'Vega' in the north-west of Behring Strait, found that the summit of the arcs was very near the geographic meridian, whereas the magnetic declension was 20° . Two auroras observed far to the south, at Benares (1847) and at Macao (1838), had their summit 20° east of the magnetic meridian. The observations of the International Polar Expeditions of 1882-83 furnished similar results. At Jan Mayen, for example, the summit of the arcs was on an average four degrees east of the magnetic meridian ; at Spitzbergen the mean deviation, out of 371 measurements, was more than eleven degrees in the same direction. In Central Europe the coincidence appears more perfect. Finally, the observations made at Hobartstown and Melbourne give a mean

deviation for the summit of the aurora of nine or ten degrees to the east of the magnetic meridian.

The study of the orientation of the crowns and of the auroral rays leads to analogous results to those furnished by a study of the arcs. In general, the point where the rays converge, or what comes to the same thing, the centre of the crown, is very near the magnetic zenith. Forty-three observations of crowns taken at Bossekop gave between these two points a mean distance of less than a degree, which is about the amount of probable error in the observations; the coincidence may therefore be regarded as perfect. But if we consider individual observations we find great divergences in detail, as in the case of the arcs. Thus on January 20, 1829, at Bossekop, the converging point of the rays of an aurora was at 15° from the magnetic zenith; on two other occasions the deviation was 12° .

In spite of these accidental deviations the mean position of the centre of the crowns seems to be at very little distance from the magnetic meridian in all countries where trustworthy observations are sufficiently numerous, as in France, England, Central Europe, &c. Thus on October 25, 1870, Heis found at Munster that the centre of the crown was exactly in the magnetic meridian and 65° from the horizon, while the magnetic inclination was 67° . The centres of the two crowns observed by Winnecke at Pulkova, April 24, 1859, and December 14, 1862,

had respectively a height of 69° and 72° , the inclination being a little less than 71° . In Spitzbergen, according to the observations of Palander in 1872 and 1873, the centre of the crowns was only on an average two degrees lower than the magnetic zenith; in the same country Carlheim Gyllenskiöld found in 1882-83 for the height of the centre of the crown, after eighty-seven measurements, $79^{\circ} 55'$, the magnetic inclination being $80^{\circ} 35'$. The same coincidence is observed in the southern hemisphere; thus the centre of the crown observed at Melbourne during the great aurora of September 2, 1859 (fig. 15), was at one degree of angular distance from the magnetic zenith.

The position of the centre of the coreal crown at Bossekop was not in perfect agreement with the hypothesis suggested by Bravais to account for the deviation of the summit of the auroral arcs to the west of the magnetic meridian, which we have indicated above. The mean position of the centre of the crowns was more than three degrees to the west of the vertical plane perpendicular to that which marks the mean direction of the auroral bands or of the arcs, and this difference is certainly greater than possible errors of observation. We must therefore admit either that the mean orientation of the bands of the aurora is not perpendicular to the magnetic meridian, or that the direction of the rays is not rigorously parallel to the magnetic needle. As the

distance between the centre of the crowns and the magnetic zenith is less than the deviation between the summit of the arcs from the magnetic meridian, it appears more rational to admit that the arcs or bands are not perpendicular to this meridian.

The conclusion of all that precedes is that the magnetic forces of the earth certainly play the principal part in the orientation of the aurora borealis. The arcs or bands tend to dispose themselves nearly perpendicularly to the magnetic meridian; and the direction of the rays is sensibly parallel to the magnetic needle. But other causes may intervene and produce notable deviations in the arcs or the rays. We shall see later that the most satisfactory theory which has yet been proposed for the aurora borealis accounts perfectly, far better than the hypotheses of Bravais, for the mean deviation of the summits of the auroral arcs from the magnetic meridian; it only remains therefore to account for the abnormal deviations, such as those which transport the summit of the arcs far from their mean position, as in the examples which we have given. The causes of these accidental deviations are yet unknown; but it seems to us that they should be sought in meteorological conditions. Different parts of the atmosphere, even at no great distances from each other, vary greatly in temperature and humidity. The electric discharges which constitute the aurora borealis encounter therefore at a given moment

strata which are unequally conductive ; hence a cause of that want of symmetry observed in the form of the auroras, and probably of the deviations in direction which we have indicated, and which are sometimes considerable.

As we have said, in a previous chapter, no very distinct relation has yet been proved between the aurora borealis and meteorological conditions ; but this is perhaps because a direct relation has been sought between the two phenomena, whereas meteorological conditions may very likely influence, not the production of the aurora, but its form and position.

2. *Relation of the aurora with magnetic disturbances.*—Independently of the phenomenon of the direction of the aurora borealis, in which the influence of terrestrial magnetism plays a chief part, the production itself of the auroras is associated, at least in many cases, with the disturbances which manifest themselves at irregular and variable intervals in the value of the different magnetic elements.

It was at Upsala in 1741 that Celsius and Hiorter pointed out for the first time the simultaneity of an aurora borealis and disturbances in the magnetic declension. Between 1741 and 1747 Hiorter noted forty-six examples of this coincidence. He recognised, however, that the two phenomena might occur separately, and that magnetic disturbance accompanied especially those auroras which were seen at

Upsala to the south of the zenith. On the request of Celsius, Graham pursued in London a series of corresponding observations to those at Upsala, and it was thus discovered that the magnetic disturbances occurred as a rule on the same day at the two stations.

These observations were afterwards continued by Wargentin, Canton, and Wilcke. The last discovered that every time, or almost every time, that magnetic disturbance is noted, it is accompanied by an aurora borealis, but that the converse does not hold; that is to say, that auroras are often seen without any perturbation of the magnetic needle.

Wilcke also studied, between 1741 and 1774, the relations of the aurora borealis with the magnetic inclination; he was the first to note the coincidence of the centre of the crown with the magnetic zenith, and showed that during the auroras the inclination is disturbed as well as the declination. Thus he observed irregular variations in the inclination which sometimes attained to a degree; he remarked at the same time that the centre of the crown altered its position in the sky in the same direction as the magnetic dipping needle.¹ Numerous observers, among whom we may mention Van Swinden, Cassini, Gilpin, &c., verified anew the discoveries of their predecessors.

¹ See on this question Wijkander, 'Ueber die magnetischen Störungen und ihren Zusammenhang mit dem Nordlichte' (*Zeitschrift der österreichischen Gesellschaft für Meteorologie*, xii., 1877).

In observations taken at Montmorency, near Paris, Coote remarked, in 1780, an interesting fact, of which we shall have more to say later, for it has a great importance in determining the nature of the relations which exist between the aurora and magnetic disturbances; it is that the magnetic disturbances seem to be the earliest in order of time, and that the magnetic needle sometimes begins to be agitated an hour before the appearance of an aurora.

Lastly, the relations of the aurora with the disturbances in the magnetic force itself, and not only with those in the direction of the needle, were discovered in 1806 by Humboldt. He announced that the horizontal factor in magnetic intensity diminishes during the prevalence of an aurora. This proposition has since been verified, notably by Hansteen, Farquharson, and Fox; Hansteen also thought that the horizontal intensity increased considerably some time before the appearance of an aurora, and then diminished as soon as the aurora became visible; the degree of this variation seeming to him to be in direct relation with the luminous intensity of the aurora. Lastly, Hansteen remarked that the magnetic perturbations sometimes last a long time; the intensity has often not recovered its initial value more than twenty-four hours after the beginning of the disturbance.

The magnetic association founded by Gauss and

Weber in 1834, and the stations organised by Sabine in a certain number of English colonies, greatly increased the number of examples of coincidences between the polar auroras and perturbations in the three elements of terrestrial magnetism: declination, inclination, and intensity. But they also testify to the complexity of the question. For though the great magnetic perturbations, which occur simultaneously in the two hemispheres, seem to be always accompanied by very extensive auroras, this is not the case with more ordinary disturbances. These often appear to be due to local causes; they are not noticed at the same time in the two hemispheres, or, in the same hemisphere, are not manifested at the same time in Europe and America. Sometimes, even, this absence of concord may be remarked in stations much nearer to each other: thus, the perturbations remarked by the French Commission at Bossekop had often no relation with those of Central Europe; the difference was especially frequent in the variations in the horizontal factor in magnetic intensity. It was then recognised that these local perturbations are not as a rule accompanied by auroras.

A great number of analogous observations might be mentioned; we will only indicate the principal results obtained by Weyprecht at the time of the expedition to Franz Josef Land on board the 'Tegetthof.'

The magnetic perturbations which accompany the aurora borealis are greater in proportion to the apparent proximity of the aurora to the spectator. Thus motionless arcs and faint auroras, or those with slow movements, are generally unaccompanied by the slightest agitation of the magnetic needle; magnetic perturbation is, on the contrary, very marked during auroras with distinct outlines, and those which present luminous rays of a defined character and rapid movements; the greatest deviations of the compass correspond to the appearance of great rays, coloured red and green, which flash suddenly like lightning.

Finally, during all the perturbations observed by Weyprecht, the needle was displaced towards the east, the horizontal intensity diminished, and the vertical intensity increased. According to Weyprecht, variations in the contrary sense, which are very rare, should be regarded solely as phenomena of reaction and not as true perturbations.

In conclusion, as long as we consider only mean latitudes, such as Central Europe and France, that is to say, countries where the aurora has generally a great altitude and extension, we find a very satisfactory coincidence between the aurora borealis and magnetic perturbations. We must not even assume *a priori* that the apparent absence of auroras during violent magnetic disturbances is an argument against this relation. For Arago has shown that if the

aurora sometimes appears to be absent during magnetic disturbance, it is often because it is too distant, and is entirely below our horizon; but it is then visible in more northern regions.

On the other hand, the relations between auroras and magnetic disturbances seem to be far less certain in high latitudes. There, perturbations are often

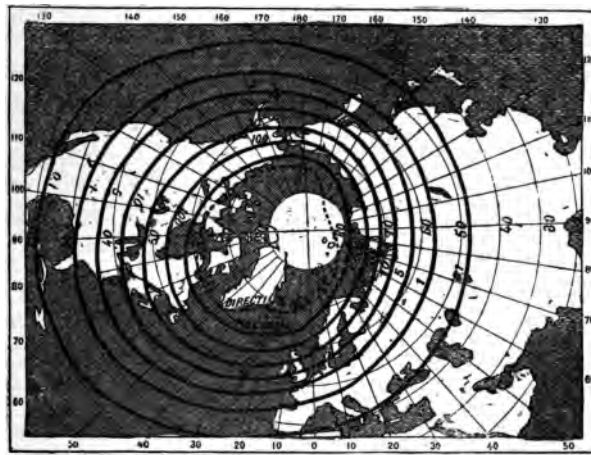


FIG. 16.—CHART OF THE FREQUENCY OF THE AURORA BOREALIS.

noticed to which no aurora corresponds; often on the contrary auroras are seen, before and during which the compass needle remains perfectly still. The relative independence of the two orders of phenomena is especially manifest in those regions which are situated within the zone of maximum frequency (see fig. 16), and in a still more marked degree in the

countries within the line of neutral direction, where the frequency of the auroras to the north is less than that of those to the south.

Thus, in his two winters spent respectively at Melville Peninsula and Port Bowen, not far from the magnetic pole, Parry never remarked any relation between the appearance of the aurora and the movements of the compass needle. Though Ross obtained a different result in the same regions and noted several times the coincidence of the two phenomena, this coincidence appears rather to be the result of chance, for McClintock observed it only five times in two consecutive winters, which confirms Parry's results. Kane arrived at a similar conclusion ; during the two winters of 1853 and 1855 which he spent at Port Van Ransselaer, at the extreme north of Greenland, he never once observed magnetic perturbation during an aurora borealis. Bessels, who sojourned yet a little further to the north, at the time of the expedition of the 'Polaris,' noted variations in the declination during one aurora only ; but that was the quite exceptional aurora of February 4, 1872, of which we have already spoken more than once, and which seems to have enveloped the whole earth, except the equatorial zone. Finally, during the wintering of the 'Alert' and the 'Discovery' in 1875-76, in the extreme north of Smith Strait, no relation was remarked between the aurora and magnetic disturbance.

The fact that in the Arctic regions the aurora

borealis is not, as a rule, accompanied by magnetic perturbation, is the more remarkable that magnetic perturbation displays in these regions an extraordinary frequency and extent. In mean latitudes, in France and Central Europe, the alterations in declination hardly exceed a fraction of a degree ; they very rarely attain to one degree, and there is no example of any perturbation having deviated the compass needle as much as two degrees from its normal direction. In Greenland and in the American Arctic regions, on the contrary, perturbations of eight to ten degrees are not uncommon. On December 24, 1858, McClintock observed at Port Kennedy movements of the needle which attained to a total amount of fifteen degrees. During the expedition of the 'Polaris,' Bessels noted a deviation of twelve degrees on February 4, 1872, a little before the appearance of the great aurora of that day ; he remarked, moreover, that on that occasion the magnetic disturbance preceded the aurora by about six hours. Finally, at Lively, on Disco I. (west coast of Greenland) O. T. Sherman observed, between August 11 and 18, 1880, a variation of $20^{\circ} 40'$ in the declination.

From all this we may conclude that there is no necessary connection between the aurora borealis and magnetic perturbation in the Arctic regions, that is to say, precisely where magnetic disturbance is most frequent and most considerable. This conclusion rests on an indisputable fact, the frequently observed

absence of magnetic perturbation during the prevalence of an aurora.

For, as we have said above, it is not possible, in strictness, to conclude anything from the apparent absence of an aurora during magnetic disturbance; but it is quite otherwise in the case of an absence of magnetic perturbation during an aurora; this absence, already noted in Europe, but exceptionally, by Wilcke, Bravais, and others, becomes the rule in Greenland and in the Arctic regions of the North of America.

These facts are of prime importance to the theory of the production of the aurora borealis. Many authors have suggested the aurora borealis as the cause of magnetic disturbance. Bravais, in particular, though he recognised that the aurora obeys with respect to its position the regular laws of terrestrial magnetism, thought that this dependence was reversed in all that concerns magnetic perturbation, and attributed the latter to the direct action of the aurora. This theory is disproved by later observations, and in two distinct ways: first of all, because in the Arctic regions auroras are frequently seen while the compass needle remains quite still; and in the second place, because when the two phenomena are manifest concurrently, it seems that the magnetic disturbance usually precedes the aurora. We have already indicated observations of this nature, among others those of Cotte, Hansteen, and Bessels; we may also mention the great aurora

australis of August 29, 1859, which was accompanied at Melbourne by violent magnetic perturbations ($1^{\circ} 9'$ for the declination) and by interrupted telegraphic communications; now these disturbances preceded the aurora, which only appeared at the moment when the telegraphic communication had begun to improve.

In conclusion, it seems to us impossible, from all the preceding arguments, to hold that the aurora borealis causes magnetic perturbation, although that is the most generally received opinion. We think rather that magnetic disturbance, or else telluric currents, determine the production of some at least of the auroras. It seems to us, moreover, that most of the difficulties which we have pointed out would disappear, notably those which result from the independence of the aurora and magnetic perturbations in certain regions, if we admitted the existence of two distinct phenomena comprised under the generic name of aurora borealis. The one, comprehending the auroras which have a great extent, that is to say, almost all the auroras of mean latitudes and some of those of the Arctic regions, manifests itself at a great height in the atmosphere, and is *always* accompanied by magnetic disturbance. This is no longer the case with the auroras of lower altitudes, of small extent, and so to speak local, which are only rarely seen outside high latitudes. Both kinds of polar auroras are, according to this theory, incapable of acting them-

selves on the magnetic needle; on the contrary, the former are, as it were, the reflection in the atmosphere of the interruption in the magnetic or electrical equilibrium of the earth. We are thus brought back by the study of the relations between the polar aurora and terrestrial magnetism to the same conclusion as that drawn from the consideration of the physical characteristics of auroras, of their altitude and periodicity; that is to say, to the belief that in the appearances summed up under the general name of polar aurora, we have two phenomena distinct in all their properties and even in their origin, which it would be desirable to consider separately henceforward if we would arrive at more accurate notions as to their nature and the laws which govern them.

3. *Relations between the polar aurora and telluric currents.*—Matteucci, at the time of the aurora borealis of October 28, 1848, remarked the coincidence of this phenomenon with interruptions in telegraphic communications, produced by telluric currents. This is the name given to currents which manifest themselves spontaneously from time to time in wires isolated throughout their length and communicating at either end with the earth. Telegraphic wires are precisely such conducting lines, and, thanks to the length and multiplicity of these lines in all directions over the whole surface of the globe, we possess most extensive information about this class of phenomena. The telluric currents which thus pass along the

telegraphic wires of some length are generally of sufficient intensity to set the electric call bell in motion, and sometimes absolutely to prevent the transmission of messages ; when they are exceptionally strong they may cause sparks and discharges of sufficient force to throw the mechanism out of gear, and even to be a source of danger to the *personnel*.

These spontaneous currents are of two distinct kinds : some occur when a violent storm takes place in the region traversed by the telegraphic wire ; these have no relation with the aurora ; but it is quite otherwise with the telluric currents proper, which manifest themselves independently of any storm, and are, moreover, distinguished from the former by marked characteristics.

When a cloud charged with electricity approaches a telegraphic line, the wire is charged, as it were, by influence, and the electrification alters when the cloud moves off. If the cloud discharges itself suddenly, at the moment of a lightning flash, for instance, the wire instantly returns to the neutral state, and a momentary current is observed to traverse the apparatus at the stations. If one end of the line be isolated the phenomena remain the same at the other extremity, and the currents are even more intense, since the wire can only be charged and discharged from the one end. Finally, these currents, which are produced by simple influence, evidently cannot occur in subterranean or submarine cables ; nor are they

observed in those wires carried through the air which are provided with a conducting envelope communicating with the soil.

It is very different with telluric currents proper, which accompany magnetic perturbations and auroras. These currents cease when one end of the wire is isolated; they are only manifested in single lines which have their return by the earth. It is not therefore an electrification by influence which is produced in the wire, but a true current, identical with the currents produced by a battery, and it results from the fact that the two points of the earth where the extremities of the wire terminate are in contact with different electric potentials. These currents may therefore occur in subterranean or submarine cables, as well as in lines above ground, as is perfectly verified by experience. Lastly, their intensity varies in direct ratio with the length of the line.

The simultaneity of auroras and these telluric currents, discovered in 1848 by Matteucci, was clearly established at the time of the great aurora observed on the nights of September 1 and 2, 1859, over the whole of the American continent, daylight alone, probably, preventing its being visible in Europe. Very interesting observations were made in France at the same date by Bergon and Blavier; we quote from the notes on the subject published by Blavier,¹ the following details:

¹ *Annuaire de la Société Météorologique de France*, vol. vii. 1859.

'At all the telegraphic stations in France the service was impeded during the whole of September 2, but especially at two periods of the day, from 4.30 A.M. to 9 A.M., and from noon to 3 P.M. These two periods were the same at all stations, and the greatest disturbances took place exactly at the same hours, at 7 A.M. and at 2 P.M. The phenomenon consisted in a current producing continuous attraction of the armatures of the electro-magnets; a galvanometer introduced into the circuit showed that the current changed its direction at varying intervals of time, of at least two minutes' duration. Towards 7 A.M. and 2 P.M. these currents were so strong that when the wire was isolated, and a conducting substance presented to it, it gave off vivid sparks. The currents manifested themselves in all directions; they seem, however, to have been more marked on the lines which went from north to south. The longest wires always showed the greatest disturbances.' The same day telluric currents were also observed in the greater part of the two hemispheres, in Switzerland, in Germany, in the British Isles, in North America, and throughout Australia. In the United States, in particular, they were so strong that for about two hours it was possible to send messages from Boston to Portland, and *vice versa* without any battery, using only the telluric current.

On May 30, 1869, during the aurora borealis which was visible from 7 to 9 P.M., Heer observed that out of the sixteen lines which terminated in the

telegraphic office at Basle, six were almost useless during the two hours that the phenomenon lasted ; on the others the telluric currents were not strong enough absolutely to interrupt communication.

Similar coincidences were also observed during the auroras of April 5 and October 24, 1870 ; and the telluric currents attained an extraordinary development during the aurora of February 4, 1872, which we have mentioned as one of the most extensive known ; it was seen in the whole of the West of Asia, in the North of Africa, throughout Europe, and on the Atlantic as far as Florida and Greenland ; at the same time an aurora was observed in part of the southern hemisphere. The disturbances in telegraphic communication were not less extensive, and were observed with great care, in great part of Europe. In Paris they began on the lines directed eastwards, those to Germany and Austria, then on that to Switzerland. In Germany all the lines were affected, and communication was for a long time impossible between Cologne and London ; in that country the most marked perturbations were observed on the lines directed east and south-east. These currents were also observed in Italy and in Turkey, on the long line from Valona to Constantinople. At the same time many of the submarine cables were so affected as to prevent the transmission of any messages ; the disturbance was especially marked on the line from Lisbon to Gibraltar, on the Mediterranean cable, on

the line from Suez to Aden, and from Aden to Bombay, and finally along the Transatlantic cable from Brest to Duxbury.

Lastly, during the great aurora of November 17, 1882, the telluric currents observed in England were, according to Preece, five times as strong as the current usually employed in telegraphy. Communication was interrupted as long as the disturbance lasted.

These examples will suffice to show the close relation existing between polar auroras and telluric currents; but it is not possible to go further and formulate this relation in precise terms. For, as a rule, telluric currents are observed in a very insufficient manner, and only when they are sufficiently strong to hamper telegraphic communications. In some few observatories there has been an attempt to organise a regular study of these currents, but as a rule too short a line has been employed, so that no general law has yet been established as a result of these observations.

There is reason to hope that this want will soon be supplied. The central meteorological office of France has lately organised at the Observatory of the Parc Saint-Maur, near Paris, a regular observation of the telluric currents, which will be prosecuted henceforward at the same time as that of terrestrial magnetism. Thanks to the valuable aid of the Administration of the telegraph service three special lines have

been constructed and reserved to this study; one lies exactly north and south, from Rosny-sous-bois to Limeil, and has a length of 14,800 metres (ten miles); the second, which is the same length, lies from west to east, from Joinville-le-Pont to Croissy. The third line is a closed circuit embracing a little less than twelve square kilometres which corresponds to a diameter of about 3,900 metres (nearly two and a half miles). On these three lines at the Observatory are placed galvanometers, whose indications are registered photographically as in the case of the magnetic instruments. These observations began in 1893, and have already led to interesting results as to the relations which exist between telluric currents and magnetic perturbations. We quote these results from the notice published by M. Moureaux.¹

The variations of the telluric current of the line which lies from east to west are of the same kind as those of the horizontal factor in the terrestrial magnetic force. The general appearance of the two curves is exactly the same. As M. Wild had already noted at Pavlovsk, a current from east to west corresponds always to an increase in the horizontal factor, and inversely. The relation between the currents of the line from north to south and the variation in magnetic declination seems less simple; the perturbations are indeed similar in extent in the

¹ *Annales du bureau central météorologique de France pour 1893*, vol. i.

two curves, but the deviations are now in the same direction and now in opposite directions; yet a current from the north to the south generally corresponds to an increase of declination, and inversely.

Airy's observations at Greenwich and Wild's at Pavolsk had seemed to indicate that telluric currents always preceded by some minutes the corresponding magnetic variations. This law is not always verified at Saint Maur; the currents often precede the magnetic variations by two or three minutes; but on the other hand the simultaneity of the two phenomena is often perfect. The question requires therefore further study. No aurora borealis has yet been observed in the neighbourhood of Paris since the study of the telluric currents has been regularly organised.

If a relation of cause and effect is proved to exist between the aurora borealis and telluric currents it remains to be discovered which of the two phenomena is the cause of the other. We have just seen that there is an intimate relation between telluric currents and magnetic disturbance, so much so that it is probable that one of the two phenomena is the cause of the other, or that they are both dependent on some yet unknown cause. In our study of the relations of the aurora with magnetic perturbation we have shown that we cannot consider the latter to be dependent on the auroras, the contrary relation being the more probable one. It is therefore probable also that

the magnetic perturbations or the telluric currents are the principal phenomenon which determines the production of auroras, or, at least, of those great auroras which are visible in mean latitudes. This opinion has been advocated by Kuhn (1861) and Balfour Stewart (1869), among others; the latter compares the earth to the centre of a Ruhmkorff's coil, of which the circuit is composed by the higher strata of the atmosphere. Electric movements are produced in these strata when terrestrial magnetism or the telluric currents undergo rapid variations. Now, as we have seen above, according to the observations of Blavier during the polar aurora of 1859, telluric currents changed their direction alternately at frequent intervals, a condition eminently favourable to the production of induction. It is therefore very probable that certain polar auroras at least are merely a secondary phenomenon, of which the immediate cause is to be found in telluric currents or in the perturbations of terrestrial magnetism. We shall return to this point when we come to discuss the theory of the polar aurora.

CHAPTER VIII.

THEORIES OF THE POLAR AURORA.

Few phenomena have given rise to so great a number of hypotheses and theories as the polar aurora; we find them already in Greek authors, from Anaxagoras, Anaximenes, and Aristotle, and it would be easy to fill a volume with the mere enumeration of these attempts at a theory, without discussing them. We will not therefore try to sketch the history of these opinions, but confine ourselves to a statement of the principal ones, and especially those which have had most influence on the study of the aurora. These theories may be classed under four heads: cosmic, optic, magnetic, and electric theories.

1. *Cosmic theories*.—In the cosmic theories of the polar aurora this phenomenon is attributed to causes completely exterior to our globe. Of the numerous theories of this nature, the most famous is that of Mairan, who wrote his 'Treatise' on the aurora borealis, to which we have so often referred, to expound and defend it. Mairan attributes the aurora to the zodiacal light, a whitish light like that of the

Milky Way, which is seen in the heavens at certain seasons of the year, in the form of a long beam of light extended along the zodiac. The first serious study of this phenomenon was that of Cassini, beginning in 1683 ; his work was continued in the following century, notably by Mairan, and it was recognised that, according to all appearances, the zodiacal light is a very much flattened ring, formed of material particles, surrounding the solar equator. The radius of this ring varies with the season, is always very large, and may exceed that of the orbit of the earth.

According to Mairan the aurora borealis is produced when the earth comes in contact with the zodiacal light ; the matter of this zodiacal light, yielding to the attraction of the earth, falls into our atmosphere and is set on fire, ' either by itself, or by its collision with the particles of the air, or by the fermentation occasioned by its mixture with the air.' Starting from this hypothesis, Mairan explains in an ingenious manner the various appearances and the periods of the aurora borealis.

This explanation appears to have been adopted at the time with enthusiasm. According to Fester, Mairan had ' lit a torch which illuminates the origin and the causes of this phenomenon.' In his treatise on meteorology (1774) Cotte speaks of ' the admirable agreement which exists between all the parts of this system and the result of the observations which the table of the aurora borealis presents to us.'

Nevertheless, the theory of Mairan encountered from the first some resolute opponents, especially Euler and Lambert. A capital objection was early made, viz., that if the aurora borealis was produced by causes external to the earth it would present an apparent movement from east to west, like the other celestial bodies. An analysis of all the Bossekop observations led Bravais to the opposite conclusion; not only the movement from east to west is not the prevailing one in the aurora borealis, but the inverse movement is the most frequent. So also the position of the earth in its orbit has no influence on the movements of the aurora. It must be added that the hypothesis of a cosmic origin renders no account of the regular daily variations which are observed in the forms of the aurora. 'These remarks,' concludes Bravais, 'appear to me destructive of any hypothesis which would attribute the aurora borealis to a cosmic matter originally foreign to our globe. How under this hypothesis can we account for the evident diurnal period which is followed by the forms of the aurora, and the absence of any similar period in its movements? How can we understand that the variation is found there where it should not exist, and is absent where it should on the contrary be found?'

These objections finally dispose of all cosmic theories, and force us to see in the aurora borealis a purely terrestrial phenomenon.

We must here note a singular coincidence which could not, of course, be known in Mairan's time, but which would have singularly increased the confidence which his theory inspired. We have seen that the light of the aurora is specially distinguished in the spectroscope by a brilliant yellowish green line, which has not yet been referred to any known body. Now this line is found also in the spectrum of the zodiacal light, as has been proved by Angstroem, Vogel, and Lockyer among others. We cannot thence conclude the identity of the two phenomena ; but if some day the source of the greenish-yellow line of the aurora is discovered, it will be at the same time a precious indication of the constitution of the zodiacal light.

Cosmic hypotheses have often been combined with other theories to explain the aurora ; we shall give some examples of these in our examination of the magnetic theories. The objections which render the purely cosmic theories unacceptable evidently apply equally to mixed theories.

Though it is impossible to admit that auroras are due to cosmic matter, coming from extra-terrestrial regions, it is on the other hand very probable that cosmic causes, foreign to our globe, may determine on our globe the production of auroras. We have dwelt at some length on the relations which exist between the sun spots on the one hand, and magnetic disturbance, telluric currents, and the aurora borealis on the other, and we have seen that these phenomena

appear to obey the successive phases of solar activity. We shall see that the electric theory of the aurora accounts for these relations. But it is of interest to remark here that the same causes appear to act upon other planets. The dark hemisphere of Venus has several times appeared to be illuminated, and Winnecke attributes to these faint illuminations a greyish violet tinge. This illumination has been observed in the years 1721, 1726, 1759, 1796, 1806, 1825, 1855 and 1871; now some of these years, notably 1726, 1759, 1865, and especially 1871, were years of great auroras on the earth. If later observation confirms this correspondence in the two phenomena we shall have the right to regard the lights which are produced on the planet Venus as true polar auroras, and a new argument will be added to all those which tend to show that the physical constitution of that planet resembles that of the earth.

2. *Optical theories.*—The optical theories of the aurora are found in germ, in a passage which we have quoted from the ‘King’s Mirror,’ a work written in Norway towards the middle of the thirteenth century: ‘Some persons think that this light (the aurora) is a reflection of the fires which surround the seas to the north and to the south; others say that it is the reflection of the sun when it is below the horizon; for my part I think that it is produced by the ice, which radiates by night the light which it has absorbed during the day.’

One of these hypotheses, that which regards the aurora as the light of the sun reflected towards us by particles of ice, is evidently derived from the relations which exist between the aurora borealis and certain cirrus and cirro-cumulus clouds. We have already dwelt upon these relations. This hypothesis has been maintained by a great number of authors, among whom are Descartes, Ellis, Frobesius, Hell, and in more modern times Sir John Franklin, Ross, Raspail, and lastly, in 1873, Wolfert. It is clear, however, that this theory encounters capital objections; it attributes to the upper regions of the atmosphere a power of reflecting light out of all proportion with that which is revealed by the phenomena of twilight. Nor can the auroras be attributed to the reflection of the light of the sun from the particles of ice which compose the cirrus clouds, for we have seen that in the Arctic regions auroras are often produced at but little distance from the surface of the earth, a few miles or even less; now it is very certain that in these regions, in winter, particles of ice cannot, at so low an elevation, be reached by the rays of the sun. A simple calculation shows that at the time of the winter solstice a point situated only in latitude 70° must, in order to receive the rays of the sun at mid-day, be at more than eleven kilometres above the surface of the earth (seven miles); at midnight it must be as much as 2,400 kilometres (1,490 miles). At the equinoxes, in order to be able to

perceive in lat. 45° , and at midnight, the reflection of the sun's rays from particles of ice, these would have to be at a height of 2,600 kilometres (1,615 miles), which is manifestly impossible. Even admitting a series of successive reflections, the altitude would still be far too great, and it would be hard to understand how after all these reflections the light would have sufficient intensity. Finally, this theory offers no explanation of the incontestable relations which connect the production of the auroras with magnetic disturbances and telluric currents. We may add that the complete absence of polarisation of the light of the aurora borealis is a direct proof that this light has suffered no reflection. Lastly, if the light of the aurora were derived by reflection from that of the sun its spectrum would be continuous and marked by black lines, identical with the solar spectrum, or very similar to it. Now we have seen that the spectrum of the aurora is very different. The absence of polarisation and the spectrum of the aurora are two characters which alone suffice to destroy absolutely the theory of reflection.

Another explanation indicated vaguely in the last phrase of the passage from the 'King's Mirror,' which we quoted above, attributes the auroral lights to a sort of phosphorescence. This simple statement is insufficient, for it would be necessary to show what is this substance which possesses so extraordinary a phosphorescence, and which has not been found in ice ;

and then it would be necessary to show how, under this hypothesis, the periodicity of the auroras, their relation with terrestrial magnetism, &c., could be accounted for. This hypothesis must therefore be abandoned like the preceding ones.

Yet it is possible that phosphorescence or rather fluorescence may play a certain part in the polar aurora, not as cause but as effect. We have said that the light of the aurora is characterised by a certain line in the spectrum of a greenish-yellow colour; its nature is unknown, but numerous spectroscopists, especially Angstroem and Rand Capron, believe it to be produced by a phenomenon of phosphorescence or fluorescence. This phenomenon in any case is only accessory, and is due to a particular condition of the passage through the air of the electric discharges which constitute the polar aurora.

3. *Magnetic theories.*—The theory known as magnetic, of the aurora borealis, is far more satisfactory than any of the preceding; it accounts better for the greater number of the phenomena, and has still a number of adherents, though it seems to us that it must yield to the electric theory.

The magnetic theory dates at least from the famous astronomer Halley, who supposed (1716) that the aurora borealis was due to a 'magnetic vapour,' luminous *per se*. Independently of vagueness in statement, this hypothesis was not at first received with favour, because at that epoch electro-magnetism

was still unknown, and experiments of the light-producing power of magnetic action had never been seen. The theory only took definite shape with Dalton (1793). After having collected and published a great number of observations of the aurora borealis, Dalton again showed the relations which existed between the aurora and terrestrial magnetism, discussed the different hypotheses on the nature of the aurora, and finally propounded the theory that the rays of the aurora are composed of ferruginous matter, magnetic in themselves, or else magnetised by the action of the earth. This dust, which takes its direction under the influence of terrestrial magnetism, with its north pole below (in the northern hemisphere) serves as a conductor to silent electric discharges between the upper strata of the atmosphere and the lower strata. Dalton concluded that it is not terrestrial magnetism which produces the auroras, but the latter which modify terrestrial magnetism and cause the perturbations.

Dalton's ideas were revived by Biot (1820), who thought that the aurora borealis might also be produced by the presence in the air of ferruginous particles by volcanic eruptions. Von Baumhauer (Utrecht, 1840) also supported the same opinions, but attributed the ferruginous particles not to volcanic eruptions of terrestrial origin, but to the fall upon our globe of cosmic dust; the light of the aurora would on this theory be produced by the

incandescence of this dust when it entered the atmosphere, as in the case of meteors and falling stars. Among the most recent defenders of this theory, more or less modified, we may mention Denison Olmsted (1856), Foerster (1870), Zehfuss (1871), Toeppler (1872), and lastly Gronemann (1875).

Among the arguments urged in favour of the magnetic theory is the existence on the soil of the Arctic regions of great quantities of ferruginous dust, and even of masses of meteoric iron. A rain of dust upon the earth has also been observed during several auroras, notably at Padua in 1834, and throughout northern Italy at the time of the great aurora of 1872. In mentioning these coincidences Toeppler also remarks that the presence round the moon of halos, which as we have said sometimes occur during an aurora, may likewise be attributed to this meteoric dust. In supposing a cosmic, not a terrestrial, origin to this magnetic dust, the magnetic theory of the aurora is thus nearly identical with that of Mairan, since many authorities believe the zodiacal light to be formed of this cosmic dust.

As a further proof in support of this magnetic theory it is also alleged that the lines in the spectrum of the aurora are somewhat near to some of those in the spectrum of iron. It is clear, too, that this hypothesis lends itself, in appearance at least, to the explanation of the relations which exist between auroras and terrestrial magnetism.

On the other hand, the magnetic theories encounter many objections. The last argument, drawn from the analogy of the lines in the spectrum of the aurora with those of iron, is far from being decisive; the lines of the auroral spectrum are only near a very small number of those of iron, and the brightest lines of this metal are not found in the spectrum of the aurora. Most spectroscopists therefore think that the spectrum of the aurora cannot be attributed to iron, and that the former shows more affinity with the spectrum of electric sparks in very rarefied air.

If an origin external to the earth is attributed to the ferruginous particles, which, according to the magnetic theory, constitute the aurora, we are confronted by the objections which we set forth previously when we dealt with the cosmic theories of the aurora. Moreover, on the hypothesis of dust from the interplanetary spaces, it is hard to understand why the aurora should never manifest itself in the equatorial region, nor why its frequency should diminish rapidly within the maximum zone, towards the north pole. If, on the other hand, we return to the hypothesis of a purely terrestrial and volcanic origin for this dust, the cause of the diurnal and annual periods of the auroras remains obscure, and also of the difference in this respect between the regions which are within, and those which are without the zone of maximum frequency.

With regard to the rain of dust which has once or

twice been observed in Europe during an aurora, it can only be regarded as a chance coincidence. No similar rain has yet been observed during an aurora by observers in high latitudes; now it is especially in those regions, where the aurora is seen almost every night and is much nearer the earth, that frequent falls of ferruginous dust would be observed, were there any relation between them and the production of auroras.

Finally, it appears to us very difficult to admit that dust, even supposing it to be formed of pure iron, could exercise on the compass needle an influence capable of producing a deviation of several degrees, while it forms at the same time clouds so transparent as to allow stars of the fourth magnitude to be seen through it.

All these reasons taken together lead us to reject the magnetic theory as we have already rejected the preceding theories.

4. *Electric theories.*—We now reach the electric theories, which are those in which we should seek for the true explanation of the aurora borealis. The first to refer the aurora borealis to a purely electric phenomenon appears to have been the physician Canton;¹ he pointed out in 1753 the close analogy which auroras offer with the light of electric discharges produced in very rarefied air. In his view the aurora

¹ Canton was the first to discover and study the phenomena of influence; he recognised also that a tube containing rarefied air becomes luminous when moved about near a charged conducting body.

was but the form which storms take in polar regions.

These ideas were adopted successively by Priestley, Eberhard, Frisi, Pontoppidan, Benjamin Franklin, &c., but without making much progress. A very similar opinion was advocated by Fisher in 1834; his theory was that auroras are a phenomenon of electric discharge due to the positive electrification of the atmosphere; they are produced at the moment when the electric equilibrium is re-established between the atmosphere and the earth, by the intermediary of particles of ice, which are imperfect conductors floating in the air, and serve to bring down to earth the electricity of the upper regions of the atmosphere. In the equatorial regions these particles of ice do not exist sufficiently near the earth; electric equilibrium can there only be re-established by storms.

Dové assigns to the auroras of mean latitudes their true origin, supposing them to be produced by magnetic disturbances of the interior of the earth; for, he says, that which can put the needle in movement over a wide extent of territory may also produce brilliant projections of light when the magnetic disturbance of the earth reaches its extreme degree. This explanation is the more remarkable that it preceded the discovery made in 1831 by Faraday of the currents of induction produced by the displacement or the variations of magnets.

Then followed the studies of A. de la Rive, which for a moment were believed to supply a complete

explanation of the phenomenon. He supposed that auroras were produced by the positive electricity which, in the upper regions of the atmosphere, is transported by the trade winds from the equator towards the poles. Arrived at the polar regions, this electricity accumulates and attracts below it the negative electricity of the earth. There would thus be a species of condensation, and from time to time discharges in the form of auroras, when the tension of the two electricities attained to sufficient values. De la Rive conceived in 1862 an apparatus which would produce luminous appearances analogous to those of the aurora. In this apparatus, which is described in most treatises on physics, a bar of soft iron which rests at one end on a powerful electro-magnet is enclosed in an electric case in which the air can be much rarefied; the bar is surrounded, except at the two ends, with an envelope of glass, and the spark of a powerful Ruhmkorff's coil is passed between the summit and the base of the bar. In these conditions a beam of light is obtained between these two points which plays round the bar of iron, and recalls in form and colour certain aspects of the auroras with rays. We do not insist on this experiment, since it requires conditions which evidently do not obtain in the atmosphere; a true explanation of the phenomenon cannot therefore be found in it. The same holds good of the beautiful appearances, also resembling auroras, which Gaston Planté obtained with his

powerful secondary battery, when the negative electrode is plunged into a vessel filled with brine, and the positive electrode is brought close to the damp walls of the same vessel.

Lemstroem¹ invented another experiment which gives results much nearer to the aurora borealis both in general appearance and probably also in mode of production.¹ An insulated metallic ball, armed with a few points, communicates with one of the poles of a Holtz machine, of which the other pole is connected with the earth. At a certain distance from this ball, and opposite to one of the points, are placed some Geissler tubes, of which the further ends are also placed on the ground, while those nearer to the ball are insulated. As soon as the Holtz machine is set in motion the Geissler tubes are illuminated; under favourable circumstances and with a good electric machine this illumination takes place when the tubes are as much as two yards away from the ball. The passage of the electricity, which is not shown by any light between the ball and the tubes, that is in air at the ordinary pressure, is thus quite sufficient to light up the very rarefied air contained in the Geissler tubes. Of all the experiments hitherto attempted in the way of reproducing artificially the effects of the aurora borealis, this is certainly the one which most nearly approaches the natural phenomenon.

Another theory, more complete than any of the

¹ *Archives des Sciences physiques et naturelles*, 1875, vol. liv.

preceding, was proposed a few years ago by Edlund.¹ We shall give it at some length, in spite of some objections which have been pointed out from the point of view of physics, because this theory, with some modifications and additions, seems to us to explain in the most satisfactory manner the different properties of the aurora borealis.

Edlund takes as his point of departure the phenomena known as unipolar induction, which were discovered by W. Weber, and which he himself has studied very thoroughly. This is the name given to those currents which arise in each half of a metallic sheath which surrounds a magnet when the sheath is rapidly revolved round the magnet. To show the production of these currents it is enough to apply two metal springs to the revolving sheath; the one should be placed opposite one of the poles, the other opposite the neutral line of the magnet; then these two springs must be connected by a circuit containing a galvanometer. The currents are produced in the same way, whether the magnet remains motionless or is dragged along in the same movement of rotation as the sheath which surrounds it.

It is known that the general phenomena of magnetism can be explained on the hypothesis that the earth contains a magnet with two poles. The earth, being a relatively good conductor of electricity and

¹ E. Edlund, 'Recherches sur l'Induction Unipolaire, l'Electricité Atmosphérique et l'Aurore Boréale' (*Actes de l'Académie des Sciences de Suède*, vol. xvi., Stockholm, 1878).

animated by a movement of rotation, is thus similar to the sheath of which we spoke above, and consequently the phenomena of unipolar induction should be produced in it.

We will suppose, to simplify the question, that the axis of the terrestrial magnet coincides with the axis of the earth's rotation, or, in other words, that the magnetic poles do not differ from the geographical poles. We know that this is not so, but we shall see later what modifications this actual difference produces in the facts. In calculating first on this simple hypothesis all the circumstances of unipolar induction, Edlund shows that a molecule charged with positive electricity, taken on the surface of the earth, is subjected to two forces—the one vertical, from below upwards, which tends to drive this molecule upwards into the air, following the direction of the radius of the earth; the other perpendicular to the first, directed along the meridian and, in each hemisphere, tending to draw the molecule towards the nearest pole. The first force is at its maximum at the equator and *nil* at the poles; the other, on the contrary, is *nil* at the equator and increases with the latitude, then diminishes and becomes *nil* again at the poles. The resultant of these forces is at each point of the earth situated in the meridian, and perpendicular to the direction of the magnetic dipping needle.

Under the influence of these forces the electrified molecules leave the surface of the earth to rise in the

atmosphere, and this effect is produced especially in the equatorial regions where the force is greatest. Electricity is thus accumulated in the higher regions of the atmosphere, and this is in agreement with the observed fact that the electric potential increases with the altitude. Now it is known, and other works of Edlund have contributed to the sum of knowledge on the subject, that very rarefied gases are good conductors of electricity; the fancied resistance of a vacuum is due to the difficulty which electricity experiences in leaving the electrode, not in traversing the surrounding medium. When it has reached a sufficient height in the atmosphere, the electricity will find strata which offer little resistance, and consequently it will be able to obey without difficulty the forces which attract it towards the polar regions.

In order to descend to the earth again this electricity has two courses open to it: either disruptive discharges through the air,—the storms of the equatorial and mean latitudes; or slow discharges in the form of continuous currents which are produced in high latitudes; these are the polar auroras. These continuous currents might be produced at the pole itself, since at that point the vertical force is *nil*; but as a general rule the electricity of the atmosphere will re-enter the earth long before it reaches the pole, provided that it follows the direction of the magnetic dipping needle, because, as we have seen above, the resultant of the forces which act on the

electrified molecules is perpendicular to this direction. In order to flow towards the earth, following this direction, in a given latitude, the electricity has only to overcome the resistance of the air. Now the quantity of electricity accumulated in the atmosphere, and consequently its tension, increases with the latitude; at a given moment then, the tension having become very great, the electricity of the upper regions of the atmosphere will flow downwards towards the earth in currents which follow the direction of the magnetic dipping needle; this flow will occur by preference in regions where, as a consequence of particular meteorological conditions, temperature, humidity, &c., the conductivity of the air is greatest. On the hypothesis of the symmetry of all the phenomena round the geographical pole, this flow of electricity would be produced in a zone of which the centre would be the pole.

In reality the poles of the terrestrial magnet do not coincide, as we supposed, with the axis on which the earth rotates. The magnetic pole of the northern hemisphere is in latitude 73° , and in longitude 98° (from Paris); but this only complicates the calculation a little, and hardly modifies the general conclusions. The tangential force, which we found to be *nil* at the geographical pole, is in reality *nil* neither at the geographical nor at the magnetic pole, but at a point situated between the two. The annular zone in which the auroras most frequently occur is not a

circle of which the centre is the geographical pole, but takes an oval form and cuts the meridian which passes through the magnetic pole at a much lower latitude on the side of the Atlantic than on the opposite side. This shows a remarkable agreement with the results of observation of the form and position of the zone of the maximum frequency of the aurora borealis.

Omitting the general phenomena of atmospheric electricity, which are also in agreement with Edlund's theory, and concerning ourselves solely with the aurora borealis, it will be seen that this theory explains satisfactorily :

1. The direction of the rays of the aurora.
2. The existence, the form, and position of the zone of maximum frequency.
3. The deviation of the summit of the arc from the magnetic meridian. For, by allowing for the geographical position, and the magnetic declination of a given locality, and also for the form and situation of the maximum of electric density, the theory of Edlund permits us to calculate the deviation of the summit of the arc from the magnetic meridian. Thus at Bossekop and at Abo this deviation should be about ten degrees to the west, while the summit of the auroral arc should approach the magnetic meridian much more nearly in North America and in Siberia. These results are in perfect agreement with the observed facts (see page 124).

4. The accidental deviations which may be produced if, as a result of particular meteorological conditions, the resistance of the air becomes much less in a direction different to that of the magnetic needle, along which the flow of electricity should normally proceed.

5. Finally, it will be seen that if this theory does not explain directly the annual and diurnal variations of the aurora, it at least allows us to foresee that the explanation may be connected with this theory, after a study of the periodic changes in the conductivity of the air resulting from the variations of the different meteorological elements.

We will conclude our review of the theories to which the aurora borealis has given birth by a sketch of the most recent of them all, that of J. Unterweger.¹

The starting point of this theory is purely hypothetical, and is not susceptible of verification; but the results to which it leads appear to agree with a great number of the observed facts; it deserves mention, therefore, in spite of its hypothetical character, among the other general theories of the aurora borealis.

It is known that the sun is not fixed in space, but that it moves with a velocity of about thirty-three miles a second towards a point situated in the con-

¹ J. Unterweger, 'Beiträge zur Erklärung der cosmisch-terrestrischen Erscheinung; über das Polarlicht' (*Denkschriften der Akad. der Wissenschaften*, vol. 1., Vienna, 1885).

stellation of Hercules. All the planets are implicated in this movement, so that the earth, instead of describing a closed ellipse, of which the sun occupies one of the foci, really moves on a sort of elliptical helix traced on a cylinder of which the axis is the path of the sun through space. As the plane of the earth's orbit cuts this axis obliquely, the absolute velocity of the earth through space presents a regular annual variation; it is greatest towards the middle of March (about forty-four miles a second), and least towards the middle of September (about thirty miles a second).

On the other hand, in order to explain the propagation of heat and light, science has been constrained to suppose the existence of an imponderable but elastic medium, ether, which transmits the vibrations of heat and light. This ether fills all the celestial spaces and also material bodies.

Starting from these data Unterweger supposes that the cosmic ether, that is to say, that which fills the celestial spaces, when it is met by the earth in its movement, of which we have just indicated the nature, is compressed or condensed in front of the earth in the direction of its movement, and dilated or rarefied, on the contrary, behind it. Thus the cosmic ether in advance of the earth would be more condensed than that which our globe bears along with it, and it would be more rarefied behind. If we admit, moreover, that the condensed ether has a positive electric potential

with regard to rarefied ether, it results that that half of the earth which presents itself first in its movement through space, and which comprehends the greater part of the northern hemisphere, will be negatively electrified with regard to the regions of space towards which it is directed ; in the same way the half of the earth which is behind, and which comprehends the greater part of the southern hemisphere, will be electrified positively with regard to the regions of space which it is leaving.

By means of his electrical apparatus Lemstroem has shown (see page 116) that in Lapland the terrestrial current at a certain distance from the earth is directed from above downwards, from the upper regions towards the earth ; this fact, on the interpretation of which we made certain criticisms, appears to agree with Unterweger's hypothesis. But this same hypothesis indicates that the terrestrial current should show a different direction in the southern hemisphere ; experiments similar to those of Lemstroem repeated in high austral latitudes, at Cape Horn or on Kerguelen Island, for instance, are of capital importance for the confirmation of this theory.

From calculations based on the rapidity of the movement of the earth, and of the inclination of the axis to the plane of the orbit, Unterweger finds that the electrification of the northern hemisphere should be at its maximum in September, and at its minimum in March. The sum of the days of aurora and of the days of storm

in many parts of our hemisphere presents this same annual variation, maximum in October, minimum in March, and this appears to Unterweger to be a first confirmation of his theory. It must be remarked that the auroras taken alone and independently of storms do not follow the same law, and that their frequency has each year, at least in most countries, two maxima—in spring and autumn.

Unterweger explains the diurnal variation of the aurora (p. 80) by adding to his original hypothesis a second, viz. that the sun has a positive electrical potential with regard to the earth. The action of the sun thus modifies the distribution of electricity in the higher regions of the atmosphere. In calculating this action, it is shown that instead of being distributed equally over all parts of a zone of the same latitude, the electricity leaves in part that portion of the zone which is turned towards the sun for that which is in shadow; in this latter portion the electricity is not distributed uniformly, but is found especially towards the west. The result is that auroras should be more frequent during the first hours of the night, and that over the whole earth, and this law is confirmed by observation.

The same reasons explain also the displacement of latitude presented in the course of the year by the zone of maximum frequency. We have just seen that under the repelling action of solar electricity the electricity of the upper strata of the atmosphere accumu-

lates especially on the side opposed to the sun, in that portion which is in shadow. Now the region of shadow has the widest surface at the equator, and narrows with the increase of latitude; the tension of the electricity spread over this region increases in proportion as the surface over which it can spread itself diminishes, and is at its maximum near the summit of the region of shadow. In calculating the position of this summit at each season, Unterweger finds that the maximum of electrification, and consequently the maximum of auroras, is situated in latitude 88° at the winter solstice, in latitude 55° at the summer solstice, and in latitude 78° at the equinoxes.

The relation of the aurora with the solar spots is explained by the supposition that the appearance of the spots coincides with a variation of the electrical potential of the sun. Finally, the relation of the aurora with terrestrial magnetism is as easy to understand on this theory as on any other electrical theory.

In conclusion, the hypotheses of Unterweger appear to explain better than Edlund's theory the annual variation, and especially the diurnal variation of the aurora; but on the other hand they render account with much less ease of a number of important phenomena, such as the direction of the arcs and of the rays, the oval form of the zone of maximum frequency, the deviation of the arc from the magnetic meridian, &c.

If Edlund's theory is not established at all points, nor free from objections on physical grounds, that of

Unterweger rests on no experimental basis; it is a tissue of hypotheses—admissible, no doubt—but of which none is proved, and probably never will be proved. To be preferred to that of Edlund, it should explain better than it does a greater number of the phenomena, which is not the case—at least, until Unterweger's theory has been further elaborated.

It seems to us, therefore, that of all the theories which we have set forth the most satisfactory in its general features is that of Edlund. It is that which should be retained, at any rate, for the present, and in its main features, and with certain restrictions. For this theory, which explains in a very simple manner the characters proper to the auroras of the polar regions, is less satisfactory with regard to the auroras of immense extent which are seen simultaneously in the two hemispheres over more than two-thirds of the surface of the globe. It is not clear why, on this theory, there should be a coincidence between the two hemispheres. It is well to recall in this connection what we have already said more than once, that it seems to us that the name of aurora is given in common to two very different phenomena.

According to this view the ordinary aurora of the polar regions, those, for example, which were observed so continuously by the French Commission at Bossekop and by Nordenskiöld during the wintering of the 'Vega,' constitute a first group of phenomena, which seem to us to be almost completely explained by

Edlund's theory. The auroras of this class are in general limited to the polar regions, and are only exceptionally seen in lower latitudes. They are local phenomena, which have a tendency to appear in oval zones, of which the centre, as indicated in Edlund's theory, lies between the geographical and magnetic poles. These auroras constitute the regular return to the earth of the electricity which in lower latitudes has been driven by unipolar induction into the higher regions of the atmosphere. It is easy to understand that this regular flow, which is moreover of no great intensity, should have no influence on the needle of the compass. These auroras are seen now at one point, and now at another of the auroral zone, at a lower or a higher latitude, according as the conductivity of the air varies with meteorological conditions, temperature, humidity, &c. If there be a stratum of cloud formed of particles of ice, this stratum will form a conductor, and this explains the intimate relations which we have noted between clouds and auroras (chap. iv. para. 2). Finally, the same theory explains the contrast in the variations of the frequency of the auroras presented by mean and polar latitudes (p. 98). For if the electricity of the upper strata of the atmosphere finds in mean latitudes favourable conditions for returning to the earth, it will flow downwards before arriving in high latitudes, and the frequency of the aurora, increasing in mean latitudes, will diminish by just so much in polar latitudes, because the elec-

tricity will have disappeared without reaching them. In order to elucidate completely the conditions in which these auroras are produced, it is necessary to discover whether they present any relation with the vertical movements of the atmosphere, whether, for example, their position has any relation with the centres of high and low pressure. But in these researches attention should be directed exclusively to these auroras of the first class, eliminating all the auroras of the second class—of which we will treat presently—and which, as they are seen simultaneously in the two hemispheres, or at least over a wide extent of territory, have clearly no connection with meteorological conditions. It would be of capital importance also to organise regular observations of atmospheric electricity, taken at a large number of stations under conditions which should be strictly comparable, so as to study the variations in the electrical potential of the atmosphere according to the latitude, a phenomenon about which we possess at present no data.

A second class of auroras, entirely different, in our opinion, from the first, comprehends the very extensive auroras which are produced simultaneously over a vast space, and often, if not always, in both hemispheres. By far the greater number of auroras seen in mean latitudes belong to this class, and they are always accompanied by marked magnetic disturbances and telluric currents. In our view, these auroras do not come under Edlund's theory, but should

be considered as a phenomenon of induction produced by the telluric currents or by magnetic perturbation. We have already indicated, in the chapter on the relations of the aurora with terrestrial magnetism and telluric currents, the principal reasons on which this opinion is based. It seems very natural to admit that any sudden interruption of the magnetic or electrical equilibrium of the globe should be accompanied by corresponding electrical movements in the electrified strata which form the upper regions of the atmosphere. Laboratory experiments with Geissler's tubes show us, moreover, that these tubes grow suddenly luminous whenever the electric field in which they are placed changes abruptly. Auroras of the second class are, on this theory, but the reflection in the upper regions of the atmosphere of modifications of the magnetic state of the earth; instead of producing these perturbations, they are, on the contrary, produced by them. Moreover, they would always have their seat at a great altitude, there where the air has a degree of rarefaction comparable to that of Geissler's tubes, that is to say, at a height of thirty or forty miles; whereas the auroras of the first class may occur much lower, and even quite close to the surface of the earth; this also accords with the results of observation.

Magnetic disturbance and telluric currents having a known relation with the spots on the sun, it becomes clear that it will be the same with auroras of the second class, without the need of seeking a direct relation

between this last phenomenon and the spots on the sun.

In conclusion, the considerations which we have just set forth account satisfactorily for the principal phenomena of the aurora borealis ; and with regard to those which they do not directly explain, such as the diurnal and annual variation, they indicate the direction in which the explanation should be sought.

Among the capital points in regard to which there is still considerable uncertainty we may mention especially the spectroscopic study of the light of the aurora. Doubtless it may be regarded as more than probable that auroras are produced by electrical discharges in very rarefied air ; but laboratory study of the spectra of the electric spark in gases has not hitherto been able to discover all the lines of the aurora, and notably the principal one, that which is most characteristic of the phenomenon. These studies should be renewed, the conditions of the experiment being varied as much as possible. Whenever the spectrum of the aurora borealis is artificially reproduced, not only one of the remaining obscure features in this phenomenon will be elucidated, but we shall obtain at the same time most valuable information as to the composition and properties of the upper regions of the air.

APPENDIX.



CATALOGUE OF THE AURORAS SEEN IN EUROPE BELOW LAT. 55° FROM 1700 TO 1890.

THIS catalogue is taken, as far as the year 1872, from the general catalogue published by Hermann Fritz,¹ which is a summary of all previous catalogues. We have confined ourselves to the appearances of the aurora borealis in Europe, and below the 55th degree of latitude. Beyond this limit, especially towards the north of Norway, the aurora is so frequent that, during certain periods, it may be seen every day; it is then, as a rule, a purely local phenomenon.

Hermann Fritz's catalogue ends in the early months of 1872; we have prolonged it to the end of 1890, using the official publications of the meteorological observatories of the following countries: Spain, Italy, France, England, Holland, Belgium, Germany, Bavaria, Saxony, Austria, Hungary, Russia. We have also searched the weekly or monthly periodicals which are devoted, partially or entirely, to meteorology.

Fritz gave, in his catalogue, a brief indication of the source of each observation. We have omitted this, for the sake of brevity; it may be found in the original when required.

It is probable that, with every care, this catalogue is still incomplete. Many faint auroras altogether escape observation. It is especially after fine auroras, when attention has been directed to this phenomenon, that observers note faint auroral lights, of which the recorded number is at first very great, and then dwindles rapidly as observation tires. The continual increase of street lighting in towns is another cause of the failure to notice the fainter manifestations of the aurora. Besides these sources of error it may be that some few auroras which have really been observed are omitted in this catalogue. We shall be grateful to any one who will supply the omissions.

¹ *Verzeichniss beobachteter Polarlichter*, Wien, 1873.

In the following catalogue we indicate, after each date, the localities where an aurora borealis has been noticed. Where the name of a country is given instead of that of a town, it signifies that an aurora has really been observed in that country but without precise indication of the place or places. A query after a date, without other indication, signifies that the author responsible for the information has mentioned an aurora borealis under that date, but without naming the country where the observation was made. The query after the name of a country indicates that the observation is doubtful, the phenomenon being undefined. Finally, when an aurora borealis was observed at the same date in different localities, we have grouped these localities according to country, and always, as far as possible, in the same order. A comma separates localities belonging to the same region; a semicolon those belonging to different countries.

- 1704. Nov. 8. Canton of Zurich.
- 1705. April 19. Zurich.
- 1706. Sept. or Oct. Upminster (England).
- 1707. Mar. 1. Berlin, Schœnberg (Altmark, Saxony).—6th.
Berlin, Schœnberg, Schneeberg.
- Aug. 5. Breslau.—6th. Breslau.
- Oct. 19. Schœnberg (traces of an aurora).—20th.
Schœnberg (traces of an aurora).—21st.
Berlin, Schœnberg.—26th. Schœnberg.—
29th. Berlin.
- Nov. 6. Berlin; Ireland.—27th. (?) Upminster.
- 1708. Aug. 9. Hereford.—10th. Hereford.—20th. London.
- Sept. 11. Jena, Halle, Leipzig, Naumburg.
- 1709. Oct. 18. Durham.—(?) (towards the end of the month.)
Holstein.
- 1710. Nov. 26. Giessen, Leipzig.
- 1715. Mar. 17. Elbing and district (western Prussia).
- 1716. Mar. 15. London (very brilliant aurora); Ukraine.—
16th. Utrecht; Brandenburg, Dantzic.—
17th. A very widely extended aurora, visible
throughout Spain, Portugal, Italy, France,
England, Switzerland, the Low Countries,
Austria, Hungary, Germany, Sweden, Russia,
North America.—24th. Switzerland; London,
Windsor.
- April 10. Wittenberg (Saxony).—11th. Paris, Valincour,
Dieppe; London, Dublin.—12th. Paris; Lon-
don, Dublin, Cottenstock; Dantzic.—20th,
21st, 22nd, 23rd, 24th. Dantzic.
- Nov. 16. Neuchâtel (Switzerland).

1716. Dec. 15. Paris.—16th. Paris.
 1717. Jan. 6. 9, 10, 11. Paris.
 — Feb. 2. Berlin.—16th. Sutton-at-Hone (England).
 — Mar. 30. Rochester.
 — April 10. London, Sutton-at-Hone; Wittenberg, Berlin.
 — Aug. 10. Hungary, Silesia; Poland; Prussia.—25th, 26th, 27th. Milan.—31st. Berlin.
 — Sept. 8, 20. Berlin.
 — Oct. 15. Paris, Berlin.
 1718. Jan. 25. Silesia, Massel.
 — Feb. 21. Reichstadt; Bohemia; Silesia; County of Hereford.
 — Mar. 4. Paris; Berlin, Breslau.—10th. Zurich—19th. Berlin.—22nd. Bohemia.
 — May 1. Berlin.
 — Sept. 16. Paris; Lynn Regis; Berlin.—17th, 22nd, 24th. Lynn Regis.
 — Oct. 22. Reichstadt; Bohemia.—23rd. Paris.
 — Nov. 23. Paris; Brandenburg.—25th. Berlin.
 — Dec. 6. Berlin, Glogau, Breslau, Eisenberg.—18th. Paris.—20th. Germany.—30th. Berlin; Mecklenburg; Hanover; Hadeln; Lynn Regis.
 1719. Feb. 11. Berlin.—12th, 13th. Massel.
 — Mar. 23. South of France; Norfolk.—24th. (?) Montauban (perhaps a confusion with the aurora of the 23rd.).—80th. Paris; Neuchâtel (Switzerland); London; France; Belgium; England.
 — April 7. Paris; Norfolk.—17th. Paris.
 — Sept. 22, 24. England.—25th. Lithuania.
 — Oct. 16. Berlin, Reichstadt, Magdeburg.—18th. Reichstadt.—22nd. England.—23rd. Halle.
 — Nov. 8. Breda; Reichstadt.—6th. Massel, Lausitz, Breda; Norfolk, Cruwys-Morchard.—8th. Berlin.—11th. Magdeburg.—13th. Berlin, Reichstadt; the whole of Saxony; Holland.—14th. Nordhausen.—16th. (?)—19th. (?)—20th. Berlin, Lausitz, Magdeburg; London, Norfolk, Cruwys-Morchard.—21st. Wittenberg; Utrecht, Breda; London, Streatham, Dublin, Cruwys-Morchard.—28th. Luzin.
 — Dec. 5. Breda; Dublin.—7th. England.—18th. Guhr.—22nd. The whole of Hungary, Bohemia; Streatham.—30th. (?)—(?) Auroras were

- observed in Paris by Maraldi in November and December; the precise dates are unknown.
1720. Jan. 2. Berlin.—3rd. Edenburg (Hungary).
 — Feb. 6. Paris, Orleans; Brandenburg.—10th. Paris;
 Brandenburg.—11th. Paris; Lynn Regis;
 Luzin.—12th. Rouen.—15th. Berlin.—18th.
 Paris; Brandenburg.
 — Mar. 9. Paris.—11th, 23rd. (?)
 — Apr. 7, 11. (?)
 — Sept. 10. Paris.—28th. London, Lynn Regis.
 — Oct. 22. (?)—27th. Nürenberg.
 — Nov. 6, 7, 20, 25. (?)—29th. Paris; Marsel.
 — Dec. 2. Corsica.—3rd. Upminster.—6th. Saxony.—
 20th. Paris.
1721. Jan. 1. (?)—17th. Paris; Lynn Regis; Giessen.—
 22nd. Paris.—23rd. Lynn Regis.
 — Feb. 11. (?)—17th. Paris, Saint Malo, Riom; Cruwys-
 Morchard; Switzerland; throughout Ger-
 many.—18th. Warsaw.—22nd. Paris.—
 23rd. Paris; Nuremberg; Hungary.—26th.
 Lehotta; Paris.—28th. Augersburg, Dantzic.
 — Mar. 1. Paris, Rennes, Saint Malo; Nimeguen; Zurich;
 throughout Germany; Warsaw.—9th.
 Cracow.—18th. Stuttgart.
 — May 28. Berlin.
 — Aug. 15. Paris.
 — Sept. 16. Giessen.—22nd. Paris; Lynn Regis; Nurem-
 berg; Weimar; Magdeburg.—28th. (?)
 — Oct. 12. Luzin; Dresden; Poland.—18th. Luzin;
 Dresden, Poland.—20th. Nuremberg.—21st.
 Paris; Magdeburg.
 — Nov. 12. Dresden.—18th. Luzin.—28th. Warsaw.
1722. Jan. 7. Paris.—8th. Paris.—9th. Paris.—11th.
 Nuremberg.—12th. Paris; Nuremberg.—
 14th. Nuremberg, Breslau.—17th. (?)—
 23rd. (?)—31st. Berlin.
 — Feb. 12. Seehausen, near Magdeburg.—18th, 16th,
 Seehausen.—20th. Paris.
 — Mar. 1. Dantzic; Königsberg.—6th. Königsberg,
 Augersburg.—7th. Nuremberg; Breslau.
 —9th. (?)—16th. Nuremberg.—24th.
 Limbach, near Dresden.—27th. Berlin.—
 29th. (?)
 — May 12. Loebau.—24th. Janer (Silesia).
 — Sept. 5. Paris; Oschatz (Saxony).—6th. Paris; Oschatz,
 Striegau, Naumburg; Seehausen.—7th.

- Seehausen.—10th. Paris.—12th. (?)—16th. Paris, London, Lynn Regis.—17th. Berlin.—18th. Berlin.—22nd. (?)
1722. Oct. 8. Limbach, Seehausen; Berlin.—7th. Berlin.—8th, 9th, 10th. Seehausen.—14th. Paris; Lynn Regis; Seehausen.—15th. Lynn Regis; Seehausen.
- Nov. 8. Seehausen.—9th. (?)—11th. Giessen.—12th, 13th. Limbach.—22nd. Dantzig.—23rd. Loebau.
- Dec. 1. Limbach.—4th. Seehausen.—7th. Berlin.—81st. Bologna.
1723. Jan. 1. Nuremberg.—8rd. Bologna, Paris, Lynn Regis, Seehausen. Twice also during this month auroras were observed at Limbach (near Dresden), but the dates are not given.
- Feb. 4. Paris.—27th. Giessen.
- Mar. 2. Lynn Regis.—8rd. Berlin.—10th. Breslau.—25th. Paris.—26th. Lynn Regis.
- April 24. Paris, Berlin.
- Aug. 27. Jauer (?).—81st. Lynn Regis.
- Sept. 1. Jauer.—17th. Jauer.
- Oct. 81. Lynn Regis, Loebau, Lausitz, Saxony.
- Nov. 1. Paris, Saxony.—5th. (?).
- Dec. 2. Paris.—7th. Jauer.
1724. Jan. 17. Nuremberg.—29th. Lemberg, Loebau.—80th. Central Europe.
- Mar. 24. Rawicz (Posen).
- May 4. Jauer.—22nd. Loebau.
- Aug. 4, 12, 17, 24, 81. Central Europe.
- Sept. 9, 22, 28. Central Europe.
- Dec. 25. Central Europe.
- Auroras were frequently observed at Paris by Maraldi during the spring and autumn of 1724, at uncertain dates; they were fainter than those of the previous year, and showed a uniform light.
1725. Jan. 8. Silesia, Lausitz, Seehausen.—9th. Paris, Silesia, Lausitz, Seehausen, Berlin.—12th. Loebau, Silesia, Lausitz.—13th. Loebau, Silesia, Lausitz, Berlin.
- Feb. 12. Berlin.
- Mar. 16. Berlin.
- April 24. Berlin.
- Aug. 22. Berlin (traces of an aurora).
- Sept. 16. (?)

- 1725 Oct. 2. Seehausen.—5th. Castle Dobbs (Ireland), Silesia, Lausitz, Jauer, Lœbau, Seehausen, Berlin.—6th. Paris, Castle Dobbs.—7th. Lynn Regis, Silesia, Lausitz, Lœbau, Breslau, Berlin, Rawicz, Poland.—8th. Silesia, Lausitz, Seehausen.—9th. Silesia, Lausitz, Lœbau.—14th, 15th. (?)
- Dec. 4. Dantzig.—5th, 6th, 7th. Dantzig, Silesia, Lausitz, Germany.—12th. (?).—17th. Kæsmark.—25th (?).
1726. Jan. 3. (?).
- Feb. 6. Lœbau.
- Mar. 6. Berlin.—17th. Coasts of Spain.—24th. Nuremberg.—28th. Berlin.
- April 2. Berlin.—23rd. Upminster.
- Sept. 5. Lœbau.—26th. Paris, Breuillepont (Eure).—27th. Breuillepont.—28th. Jauer.
- Oct. 9. District of Brandenburg.—10th. (?).—14th. Paris, Lynn Regis.—15th. Lynn Regis.—19th. Portugal, Cadiz, the whole of Italy; of Switzerland; of France; of England; Brussels, Liège; the whole of Germany.—20th, 21st. Helmstædt.—22nd. Dantzig.
- Nov. 4. Provence.—6th. Lynn Regis.
- Dec. 1. Germany; Lœbau, Eisemark, Seehausen, Wittenberg, &c.—7th. (?).—16th. Montpellier.—18th. Versailles; Geneva; Nuremberg; Berlin.—23rd. Berlin.
1727. Jan. 15. Giessen; Durkheim (Hardt); Petworth.—16th. Neuchâtel (Switzerland), Liverpool, Lancashire.—17th. Paris.
- Feb. 9, 11. Utrecht.—13th. Bologna, Utrecht.
- Mar. 11. Italy.—18th. France, Petworth.—14th. Bologna, Paris, Petworth, Liverpool, Lynn Regis, Kæsmark.—15th. Germany.—16th. Bologna, Lynn Regis.—17th, 18th, 19th, 20th. Bologna.—29th. Italy.
- April 8. Lœbau, Nuremberg.—14th. Frankfurt on the Oder.—14th. Germany.
- May 13. Bologna.
- Aug. 1. Lœbau.—22nd. Königsberg (?), Germany.—27th. Königsberg (?), North Germany.
- Sept. 9. Lœbau.
- Oct. 13. Germany.—14th. Paris, Lœbau.—17th. Bologna, Germany.—18th. Bologna.—19th. Paris, Wittenberg.—20th. Wittenberg.

1727. Nov. 6. Germany.
 Numerous auroras were observed by Maraldi during the spring, autumn, and winter of 1737; the most remarkable are given above, under their dates.
1728. Jan. 8. Bologna.—19th. (?).
 — Feb. 7. Utrecht.—9th. Utrecht, Lœbau.—11th. Utrecht.—18th. Paris, Utrecht, Berlin.—21st, 23rd. Utrecht.—26th, 29th. Lœbau.
 — Mar. 1. Utrecht.—8th. Plymouth.—20th. Utrecht, Kœsmark.—26th, 27th. England.—29th. Germany, Lœbau.—30th. Utrecht.—31st. Bologna.
 — April 2. Bologna, Windsor, Plymouth, Utrecht, Teschen, Dantzic.—3rd. Plymouth.—4th. Wittenberg.—9th. Italy, Utrecht.—12th. Utrecht.
 — May —. (?).—30th. Bologna.
 — June —. Germany.—20th. Wittenberg.—25th. Berlin, Wittenberg.—29th. Paris, Wittenberg.
 — July —. Utrecht.—13th. Bologna, Plymouth, Berlin.—15th. Plymouth.—16th. Paris, Utrecht.—28th. Plymouth.
 — Aug. 2, 29. Paris, Plymouth.—30th. Lœbau.—31st. Plymouth, Utrecht.
 — Sept. 15. Paris, Utrecht.—17th. Berlin.—26th. Italy.—29th. Germany.—30th. Utrecht.
 — Oct. 2. Bologna, Breuillepont, Upminster, Utrecht, Zurich, Lœbau.—4th. Germany.—7th. Utrecht, Berlin, Lœbau, Wittenberg.—12th. Plymouth, Utrecht.—14th, 20th. Lœbau.—24th. Windsor, Rodbridge (near Southampton).—25th, 26th. Plymouth.—29th. Utrecht.—30th. Italy, Utrecht.
 — Nov. 2. Plymouth, Utrecht, Wittenberg.—4th. Utrecht.—8th. Germany.—11th, 12th. (?).—13th. Utrecht, Berlin.—23rd. Windsor, Utrecht.—24th. (?).
 — Dec. 2. Bologna.—3rd. Plymouth.—4th, 14th. Germany.
 Auroras frequently observed in Paris by Maraldi in all seasons of 1728.
1729. Jan. 17. Paris, Plymouth, Lœbau.—18th. Luzin, Rawicz.—20th, 24th. Germany.
 — Feb. 8, 11, 16. Lœbau.—17th. Germany.—18th. (?).—25th. Lœbau.
 — Mar. 2. Lœbau.—27th. Utrecht, Lœbau.—28th. Utrecht.

1729. April 6. Lœbau.—19th. Germany.—22nd. Plymouth.—
80th. Lœbau.
— May 1. Lœbau.—2nd, 17th. Plymouth.—22nd. Lœbau.
—29th. Paris, Lœbau.—31st. Helinstædt.
— June 15, 26. Paris.
— July 7. (?).
— Sept. 15. Paris.—23rd. Plymouth.—26th, 29th. (?).
— Oct. 2. (?).—11th. Lœbau.—13th. Paris.—16th. Lœbau.
—21st. Utrecht.—22nd. (?).—24th Lœbau.
—25th. Plymouth.
— Nov. 16. Paris, Plymouth, Utrecht, Nimeguen, Leipzig,
Wittenberg, Lœbau, Halle, Helmstædt, Ber-
lin, &c. (nearly all Germany).—17th. Paris,
Lœbau, Warsaw.—19th. Brussels, Nime-
guen, Lœbau.
— Dec. 17, 18. Lœbau.
1730. Jan. 8. Wittenberg.—9th. Paris.—16th. Lœbau.
— Feb. 4. Paris.—5th, 7th. Lœbau.—9th. Lœbau.—11th,
13th. (?).—15th. Rome, Florence, Bologna,
all the south of France (Provence, Langue-
doc), Paris, Utrecht, Zurich, Geneva, Berne,
Eperies (Hungary), Lœbau, Brieg (Silesia),
Warsaw.—16th. Lœbau, Brieg (Silesia),
Warsaw.—17th. Lœbau.—20th. (?).
— Mar. 8. Bologna.—6th. Bologna, Béziers, Toulouse,
France, Plymouth, Utrecht, Germany.—7th.
Toulouse.—8th. (?).—9th. Lœbau, Germany.
—11th. Bologna.—13th. Rome, Bologna.—
15th. Rome.—16th. Lœbau.—18th. Bologna.
20th. Plymouth.—21st. Bologna.—28th. (?).
— April 12. Lœbau.—13th. Germany.—16th. Italy, Bel-
gium, Lausitz.—20th. Germany, Bologna.
— May 9. Lœbau.
— June 5. Zurich.—21st. Bologna, Germany.
— July 5, 6. Lœbau, Germany.—17th, 19th. Germany.—
21st. Kæsmark.
— Sept. 8. Plymouth.—10th. Utrecht.—11th. Italy.—28th.
Lœbau, Wittenberg.—30th. Halle, Helm-
stædt.
— Oct. 4. Lœbau.—5th. Wittenberg, Halle.—6th. Wit-
tenberg.—7th. Toulouse, South of France,
Paris, Plymouth, Wittenberg, Helmstædt,
Halle, Lœbau.—8th. Berlin.—9th. Poitiers,
Paris, Breuillepont, Picardy, Frankfurt-am-
Main, Wittenberg, Berlin.—11th. Helmstædt,

- Germany.—13th. Berlin.—20th. Wittenberg, Helmstædt, Lœbau.—21st. Lœbau.—22nd. Germany.—26th. Geneva, Neuchatel, Bötterkinden, Zurich, Lœbau, Germany.
1780. Nov. 2. Paris, Vienne (Dauphiné), Geneva, Neuchatel, Zurich, Lœbau, Helmstædt, Berlin, Brandenburg, Dresden.—3rd. France, Helmstædt.—4th. Helmstædt, Lœbau.—5th. Utrecht, Helmstædt, Lœbau.—6th. Utrecht, Lœbau.—7th, 8th. Helmstædt.—19th. Lœbau.—25th. (?).—28th. Germany.
- Auroras were seen in Hungary towards the end of the month.
- Dec. 8, 16, 22, 25. Lœbau.—28th. Jaroslaw.—29th. Lisbon, Elvas, Campo Maior, Evora, and other parts of Portugal.—31st. Warsaw.
1781. Feb. 10. Bologna.
- Mar. 2. Plymouth.—7th. Utrecht.
- April 3, 13. Utrecht.—27th, 29th. (?).
- May 7. Plymouth.—14th. Utrecht.
- Aug. 22. Plymouth.—28th, 31st. Wittenberg.
- Sept. 24. Plymouth.—26th. Breuillepont, Berlin.—27th, 28th, 29th, 30th. Breuillepont.
- Oct. 2. Breuillepont, Utrecht, Altorf (Bavaria).—3rd, Breuillepont, Utrecht, Berlin, Helmstædt.—4th. Breuillepont, Berlin, Helmstædt, Hildesheim, and to the south of the Danube.—8th. Breuillepont, Plymouth, Utrecht, Nuremberg, Giessen, Helmstædt, Wittenberg, Hildesheim, Brandenburg.—10th. Wittenberg, Helmstædt.—24th, 25th, 26th. Breuillepont.—29th. Helmstædt.
- Nov. 6. Utrecht.—11th. Helmstædt.—30th. Utrecht.
- Dec. 30. Plymouth.
1782. Jan. 26. Wittenberg.—28th. Paris and neighbourhood.—29th. Plymouth.
- Feb. 2, 4, 5. Paris and neighbourhood.—7th. Wittenberg.—15th. Paris and neighbourhood.—18th. Plymouth.—20th, 21st. Germany.—26th. Italy.—29th. Paris; Wittenberg.
- Mar. 1. Paris.—2nd, 10th. Paris and neighbourhood.—14th, 18th. Germany.—21st. Utrecht, Berlin, Helmstædt, Wittenberg.—22nd. Germany.—23rd. Paris and neighbourhood.—24th. Italy.—26th. Paris and neigh-

- bourhood.—27th. Utrecht; Helmstædt.—
28th. Paris and neighbourhood.
1782. April 8, 14, 16, 17. Paris and neighbourhood. — 24th.
Wittenberg, Berlin.—23rd, 26th, 27th. Paris
and neighbourhood.
- May 12, 14, 19, 20, 23, 25, 26. Paris and neighbourhood.
—27th, 28th, 30th. Utrecht.
- June 25. Helmstædt.—26th. Paris; Helmstædt.
- July 12. Meudon (near Paris).—17th. Paris and neigh-
bourhood.—21st. Italy.—29th, 30th. Paris
and neighbourhood.
- Aug. 12, 14, 15, 16, 19, 21. Paris and neighbourhood.—
22nd. Paris, Utrecht, Altorf (Bavaria),
Wittenberg, Berlin, Dantzic.—23rd. Coburg.
- Sept. 1. Paris.—5th. Paris and neighbourhood.—10th.
Breuillepont, Wittenberg, Berlin.—11th,
16th. Paris and neighbourhood.—19th, 20th,
21st. Paris, Breuillepont.—23rd, 24th, 25th.
Germany.—27th. Breuillepont; Utrecht;
Berlin.
- Oct. 1, 2, 3. Breuillepont.—5th. Paris, Breuillepont;
Berlin. — 6th. 14th. Breuillepont.—20th.
Breuillepont.—22nd. Paris; Utrecht; Berlin.
— 23rd. Paris, Breuillepont; Utrecht,
Helmstædt; Wittenberg, Berlin. — 24th,
25th, 26th. Breuillepont.
- Nov. 4. Breuillepont.—9th. Paris.—10th. Utrecht.—
12th. Utrecht, Germany.—19th. Utrecht.—
20th. Italy, Utrecht, Germany.—21st.
Utrecht.
- Dec. 4, 13. Neighbourhood of Paris.
1783. Jan. 19. Paris and neighbourhood.
- Feb. 18. Plymouth.—14th, 16th. Neighbourhood of
Paris.
- Mar. 3. Bremen, Berlin.—8th, 9th, 13th. Neighbour-
hood of Paris.
- April 1. Plymouth.—2nd, 4th, 5th, 6th, 7th, 8th, 9th,
10th, 12th. Neighbourhood of Paris.—13th.
Neighbourhood of Paris, Landshut (Silesia).
—18th, 19th. Utrecht.—22nd. (?)
- May 4. Utrecht.—6th. Neighbourhood of Paris.—7th.
Utrecht.—9th. Neighbourhood of Paris,
Utrecht, Wittenberg.—17th. Utrecht.
- June 20. Neighbourhood of Paris.
- July 7. Italy, Plymouth, Leipzig, Wittenberg, Berlin.
—8th, 9th, 10th, 11th, 12th, 13th, 14th,

- 15th. Neighbourhood of Paris.—21st. Paris, Plymouth.—22nd. Paris.
1738. Aug. 3, 4. Paris.—5th, 6th. Neighbourhood of Paris.—7th. Paris.—8th, 9th, 14th. Neighbourhood of Paris.—17th, 19th, (?)—29th. Neighbourhood of Paris.
- Sept. 2, 3. Neighbourhood of Paris.—5th. Utrecht.—6th. Neighbourhood of Paris; Utrecht.—19th. Plymouth.—27th. Breuillepont.
- Oct. 2. Breuillepont.—3rd. Breuillepont; Berlin.—4th, 5th, 6th, 7th, 8th, 9th. Breuillepont.—10th. Paris, Breuillepont; Utrecht.—16th, 28th, 30th, 31st. Breuillepont.
- Nov. 7. Paris; Plymouth; Wittenberg, Berlin.—8th, 12th, 18th, 23rd, 24th. Paris.
- Dec. 8. Paris, Plymouth.—9th. Paris.—10th. Paris, Plymouth.—22nd. Berlin.—23rd. Utrecht.—27th, 30th. Paris.
1734. Jan. 8. Neighbourhood of Paris (?).—9th. Servian, near Béziers.
- Feb. 2. Wittenberg.—3rd. Paris; Utrecht: Berlin, Wittenberg.—18th. Neighbourhood of Paris.—22nd. Paris, Bayeux.—26th. Neighbourhood of Paris.
- Mar. 1. Berlin.—8th. Neighbourhood of Paris.—22nd. Utrecht.—25th, 26th (?).—28th, 30th, 31st. Neighbourhood of Paris (it was not possible to determine whether the phenomenon observed was an aurora borealis, or the zodiacal light).
- Apr. 2, 4. Paris (doubtful).—5th. Neighbourhood of Paris.—7th. Neighbourhood of Paris, Utrecht.—8th. Paris; Utrecht.—9th. Utrecht; Wittenberg.—10th. Bologna.—22nd. Potsdam.
- May 1, 4, 5, 6. Utrecht.—24th. Neighbourhood of Paris; Utrecht.—25th, 26th. Plymouth; Utrecht.—27th, 28th, 29th, 30th, 31st. Utrecht.
- June 1, 2, 4, 5, 7, 24. Utrecht.
- July 2. Paris.—5th, 6th, 7th, 8th. Utrecht.
- Aug. 6, 7, 8. Utrecht.—20th. Wittenberg.—23rd, 24th, 25th, 26th, 30th. Paris and neighbourhood.—31st. Paris.
- Sept. 5, 10. Utrecht.—19th. Nointet (near Beaumont), Altorf (Bavaria); Berlin.—20th. Paris, Nointet; Plymouth.—21st. Utrecht.—23rd.

- Nointet; Berlin.—25th. Utrecht.—27th.
 Nointet.—29th. Paris; Utrecht.
1734. Oct. 1, 2, 5, 6. Utrecht.—10th. Nointet.—14th. Utrecht.
 —19th, 21st, 23rd, 25th, 26th, 27th, 28th,
 29th. Neighbourhood of Paris.—30th. Paris.
- Nov. 14, 15, 17, 22. Neighbourhood of Paris.
- Dec. 19. Utrecht.—25th. Paris, Rouen; Utrecht.—27th.
 Berlin.
1735. Jan. 28. Utrecht.—25th. Berlin.—26th. Utrecht;
 Berlin, Wittenberg.
- Feb. 11. Utrecht.—21st. Italy.—22. Italy; Paris;
 Utrecht; Berlin, Wittenberg.—23rd.
 Utrecht.
- Mar. 1. Utrecht.—2nd. Utrecht; Brandenburg.—13th,
 15th. Berlin.—16th, 17th, 19th. Utrecht.—
 20th. Haarlem; Germany.—22nd. Utrecht;
 Wittenberg.—23rd. Utrecht, Haarlem;
 Berlin.—24th. England; Utrecht; Witten-
 berg; Berlin; Brandenburg.—25th. Italy;
 Utrecht; Wittenberg.—26th, 27th, 28th,
 29th, 30th, 31st. Utrecht
- Apr. 20. Utrecht.—22nd. Utrecht; Potsdam, Verden.—
 23rd. Utrecht, Haarlem; Berlin, Potsdam,
 Brandenburg.—25th (?)
- May 14, 17, 18, 19, 22. Utrecht.
- June 9, 10, 11, 13, 14. Utrecht.
- July 2, 8, 8, 10. Utrecht.—17th. Utrecht, Haarlem.
- Aug. 6, 9, 12, 19, 20, 21, 23. Haarlem.—31st. Plymouth.
- Sept. 24. Woodford, near London.
- Oct. 14. Plymouth.—15th. London, Plymouth.—22nd.
 London.—23rd. Plymouth; Verden.—24th.
 Utrecht.—25th. Wittenberg.
- Nov. 10, 11. Utrecht.—14th. Utrecht; Wittenberg.—
 18th. Verden.
- Dec. 8. Verden.—11th. Utrecht.—13th, 15th. Verden.
1736. Jan. 22. London; Utrecht.—31st. Utrecht.
- Feb. 2. Utrecht.—9th. Brandenburg.—17th. Ply-
 mouth; Altorf.—18th. Plymouth.—27th.
 Cambridge.
- Mar. 1. Plymouth.—3rd. Utrecht.—15th. Italy;
 Utrecht; Brandenburg.—21st. Branden-
 burg.
- April 3. Utrecht.—5th. Utrecht; Wittenberg, Branden-
 burg.—11th. Utrecht.—14th. London;
 Utrecht.—27th. Utrecht.
- May 4. Bologna.—6th, 11th, 14th, 15th, 27th. Utrecht.

1786. June 1, 2, 23, 24, 29, 30. Utrecht.
 — July 7, 8. Italy.—25th. Utrecht.
 — Aug. 12. Berlin.—13th. Utrecht.
 — Sept. 3. Utrecht, Berlin, Wittenberg.—4th. Berlin, Wittenberg.—5th, 9th. Plymouth; Utrecht.—17th. Berlin.—25th. Bologna; Sheffield; Utrecht.—28th. Utrecht.—29th. Utrecht; Brandenburg.—30th. Italy.
 — Oct. 1, 4, 6. Utrecht.—7th. Plymouth; Utrecht; Brandenburg.—8th. Plymouth.—10th. Utrecht; Berlin, Wittenberg.—11th, 12th. Utrecht.—20th. Utrecht; Brandenburg.—22nd. Coburg.—25th. Paris; Utrecht; Berlin.—26th. Coburg; Wittenberg; Brandenburg.—27th. Sheffield; Utrecht; Coburg; Wittenberg; Brandenburg.—28th. Utrecht; Coburg; Silesia; Pomerania.—29th. Sheffield; Utrecht; Coburg.—30th. Utrecht; Coburg.—31st. Utrecht.
 — Nov. 1. Utrecht.—6th. Berlin.—7th. Plymouth; Utrecht.—8th. Utrecht; Berlin.—9th, (?).—10th, 11th, 12th. Utrecht.—18th. Plymouth; Utrecht.—19th. Plymouth; Berlin.—20th, 21st. Utrecht.—24th. Plymouth; Utrecht; Coburg.—25th, 26th. Utrecht.—29th. Sheffield.
 — Dec. 15, 18. Utrecht.—22nd. Paris.—29th, 30th. Utrecht.
 1787. Jan. 1. Italy.—4th. Utrecht; Berlin.—19th. Utrecht.—20th. Utrecht; Berlin.—21st. Paris.—24th. Bologna.—29th, 30th, 31st. Utrecht.
 — Feb. 2, 20, 28. Utrecht.
 — Mar. 1, 4, 8. Utrecht.—18th. Plymouth.—21st. Sheffield.—28th. Berlin, Wittenberg.—29th. Plymouth; Wittenberg.
 — April 7. Wittenberg.
 — May 3. Utrecht.
 — June 1. Bologna.—4th, 5th, 17th, 18th, 23rd, 24th. Utrecht.—30th. Bologna.
 — July 26. Utrecht.
 — Aug. 20. Berlin, Wittenberg; Brandenburg.—21st. Italy; Plymouth; Utrecht; Wittenberg.—22nd. Plymouth; Utrecht; Berlin.—23rd. Plymouth; Berlin, Brandenburg.—24th. Berlin.—25th. Italy; Berlin.—26th, 27th, 28th. Utrecht.
 Sept. 13. Sheffield; Bohemia.—17th, 19th. Utrecht.—

- 22nd. Brandenburg; Goslar.—27th, 28th, 30th. Sheffield.
1737. Oct. 1. Sheffield; Utrecht.—2nd. Sheffield.—17th, 18th. Utrecht.—23rd. Brandenburg.—24th, 25th. Sheffield.—30th. Utrecht.
- Nov. 12. Plymouth; Brandenburg.—16th. Dantzic.—18th. Plymouth.—19th, 20th. Utrecht; Berlin.—26th. Wittenberg.
- Dec. 5. Utrecht.—15th. Utrecht; Coburg.—16th. Lisbon; Rome, Bologna, Florence, Ravenna, Arimini, Venice, Paris, England, Utrecht, Vienna, Saxe, Meissen, Annaberg, Schneeberg, Wittenberg, Helmstädt, Berlin, Duisburg, Brandenburg, Dantzic, Pologne.—18th. Utrecht.—19th, (?) 21st, 22nd. Italy.—24th, Arimini.—26th. Utrecht.—28th. Italy. Utrecht, Coburg.
1738. Jan. 8. Brandenburg.—25th. Plymouth; Utrecht.—26th. Utrecht.
- Feb. 8, 12. Utrecht.—16th. Italy.—18th, 19th, 24th, 26th. Utrecht.
- Mar. 11, 17. Utrecht.—18th. Sheffield; Utrecht.—21st, 22nd, 23rd, 26th. Utrecht.
- April 10. Sheffield.—13th. Utrecht.—16th. Plymouth.—18th, 21st. Utrecht.
- May 9, 12, 13, 15. Utrecht.
- June 5, 8, 16, 17, 23. Utrecht.
- July 10. Utrecht.—11th. Italy.—16th, 21st. Utrecht.
- Aug. 7. Utrecht.—13th. Bologna.
- Sept. 16. Utrecht; Berlin.
- Oct. 6, 12, 17, 18. Utrecht.
- Nov. 1. Plymouth.—4th. Plymouth; Utrecht.—5th. Plymouth.—7th. Plymouth; Utrecht.
- Dec. 4. Wittenberg.—31st. Utrecht.
1739. Jan. 8. (?)—27th. Helmstädt.
- Feb. 1. Utrecht.—13th or 14th. Helmstädt.—15th. Sheffield.—17th. Helmstädt.—27th. Helmstädt; Brandenburg.
- Mar. 6. Sheffield, Plymouth.—7th. Sheffield.—10th. Bologna, Utrecht.—11th. Utrecht.—12th. Sheffield, Plymouth, Utrecht, Helmstädt.—13th, 20th. Utrecht.—22nd. Helmstädt.—26th. Plymouth.—28th. Utrecht.—29th. Bologna, Padua, London, Chelsea, Utrecht, Helmstädt, Brandenburg.

- 1739 April 2. Berlin.—5th. Utrecht.—10th. Plymouth;
Wittenberg.—14th, 15th, 19th. Utrecht.—
24th. Berlin.—29th. Utrecht.
- May 1. Plymouth, Utrecht, Brandenburg.—2nd, 8rd,
4th, 5th, 6th, 8th, 9th, 10th, 11th, 12th.
Utrecht.
- June 2. Bologna; Utrecht.—5th, 23rd. Utrecht.
- July 6, 7, 12, 15, 23, 31. Utrecht.
- Aug. 1, 6, 7, 10, 12, 13, 28. Utrecht.
- Sept. 1, 8, 10. Utrecht.—14th, Dantzig.—23rd, Ply-
mouth; Utrecht.—24th, Sheffield, Plymouth;
Utrecht; Brandenburg.—25th, 26th. Shef-
field.—28th. Utrecht; Wittenberg.—29th,
30th. Sheffield.
- Oct. 3, 9, 24, 25. Utrecht.—29th. (?)—30th, Plymouth.
—31st. Wittenberg, Brandenburg.
- Nov. 2. Sheffield.—16th. Italy.—21st. Utrecht.—23rd.
Sheffield.
- Dec. 6. Sheffield.
1740. Jan. 12. (?)—27th. Rome.—30th. Utrecht.
- Feb. 22. Plymouth.
- Mar. 23. Plymouth; Utrecht.—24th, 25th. Plymouth.
—28th. Hornburg near Halberstadt.
- June 7. Plymouth.
- Oct. 17. Sheffield.
- Nov. 3. Saint-Port.—18th. (?)
1741. Jan. 13. Italy.—20th. Utrecht.—22nd. Utrecht;
Brandenburg.—23rd. Utrecht; Schneeberg,
Wittenberg.
- Feb. 3, 6. Utrecht.—21st. Brandenburg.
- Mar. 4. (?)—5. Sheffield.—6th. (?)—11th. Sheffield;
Utrecht.—12th, 13th. Utrecht.—16th.
Plymouth, Sheffield; Utrecht; Brandenburg.
—17th. Sheffield.—20th. Sheffield, Ply-
mouth.—21st. (?)—29th. Utrecht.
- April 1. Plymouth.—6th. (?)—9th, 16th. Utrecht.—
17th. (?)—30th. Utrecht.
- May 7, 8, 9, 10, 12, 15, 18, 30th. Utrecht.
- July 10, 23. Plymouth.
- Aug. 10. Utrecht; Brandenburg.—13th. Utrecht; Wit-
tenberg.—20th, 22nd, 31st. Utrecht.
- Sept. 1, 3, 4, 12, 19, 20. Utrecht.
- Oct. 1. (?)—2nd. Plymouth; Utrecht; Brandenburg.
—3rd, 4th, 5th. (?)—8th. Bologna; Ply-
mouth; Utrecht; Brandenburg; Wolfsburg

- (Lunebourg).—9th. Bologna; Wolfsburg.—13th, 14th, 15th, 28th. Utrecht.
- 1741 Nov. 2. Utrecht; Wittenberg.—8th. (?).—9th. Wittenberg.—12th, 28th. Utrecht.
- Dec. 14. (?).
1742. Jan. 2. (?).—13th, 14th, 23rd. Utrecht.—26th. Brandenburg.—29th. Utrecht; Berlin.
- Feb. 7. Dantzic.—12th, 13th. Utrecht.—23rd. Berlin.—25th. Wittenberg.
- Mar. 8. Plymouth; Wittenberg.—7th, 8th. Delft.—13th. Utrecht.—16th, 17th. Plymouth.—26th, 27th. Plymouth; Berlin.—28th. Utrecht.
- April 2, 3. Utrecht.—4th. Plymouth.—8th, 10th, 24th, 29th, 30th. Utrecht.
- May 23. Wittenberg.
- Aug. 26, 30. Wittenberg.
- Sept. 7. (?).—10th. Wittenberg.
- Oct. 9, 22, 23. (?).—27th. Utrecht.
- Dec. 22, 26. Wittenberg.—28th. Utrecht.
1743. Jan. 1, 8. Utrecht.—23rd. Plymouth.—30th. Wittenberg.
- Feb. 19. Berlin.
- Mar. 7. Görlitz, Berlin, Breslau, and probably Dantzic.—16th. Wittenberg.—19th. Plymouth; Utrecht; Berlin, Dantzic, Zwanenburg.—20th. Utrecht; Wittenberg.—24th. Italy; Utrecht.—26th. Utrecht; Wittenberg.—30th. Utrecht.
- April 12. Plymouth.
- July 9. Plymouth.
- Aug. 9. Utrecht; Zwanenburg.—12th. Utrecht.
- Sept. 2. (?).—8th, 9th, 18th. Utrecht.—19th. Wittenberg.—29th. (?).
- Oct. 7. Utrecht.—8th. Wittenberg.—25th. Zwanenburg; (?).—29th, 31st. (?).
1744. Mar. 4. Berlin.—19th. The whole of Lithuania.
- April 2. Plymouth; Utrecht; Wittenberg, Berlin, Dantzic, Zwanenburg.—5th, 13th, 17th. Utrecht.
- May 5, 16, 27. Utrecht.
- July 16, 17. Utrecht.
- Oct. 3. Bologna.
- Nov. 11. (?).—25th. Tübingen.
- Dec. 3. Glarus.—25th. Plymouth.—29th. Tübingen.
1745. Jan. 4. Plymouth.—10th. Utrecht.—18th. Stuttgart, Tübingen.—21st. Wittenberg; Berlin.
- Feb. 4, 8. Utrecht.—17th. Stüblau, Fürstenwerder.—

- 19th. (?)—20th. Plymouth.—(?). Plymouth (date not given).
- 1745 April 18, 19, 28. Utrecht.
 — May 19, 30. Utrecht.
 — Aug. 2. Utrecht.
 — Oct. 9, 17. Italy.—31st. Berlin.
1746. Jan. 12. Zwanenburg.—26th. Utrecht.—31st. Tübingen.
 — Feb. 4. Tübingen.—20th. Plymouth.—23rd. Berg am Irchel (canton of Zurich).—26th. Utrecht.
 — Mar. 10. Plymouth.—19th. Utrecht.—25th. Plymouth, Utrecht, Zwanenburg.—26th. Utrecht.
 — April 20, 21. Utrecht.
 — May 7, 12, 16, 17, 26. Utrecht.
 — July 14, 20, 22. Utrecht.
 — Aug. 20, 21, 25. Utrecht.
 — Sept. 21. Berlin (?).
 — Oct. 13. Schneeberg.—18th. Plymouth.—19th. Dantzig.—22nd. Utrecht, Tübingen.—23rd, 24th. Tübingen.—26th, 28th. Tübingen, Bernhausen.
 — Nov. 10. Tübingen, Bernhausen.—17th. Wittenberg.—20th. Tübingen, Bernhausen.
 — Dec. 7, 18, 24. Tübingen, Bernhausen.
1747. Jan. 6. Utrecht, Zwanenburg.—8th. Plymouth, Utrecht.—9th, 10th, 11th. Utrecht.—13th. Plymouth.—22nd. Tübingen.
 — Feb. 1, 7. Utrecht.—13th. Tübingen.—16th. Utrecht.
 — Mar. 10. Zwanenburg.—17th. Zwanenburg, Berlin.—26th. Tübingen.
 — April 2. Plymouth, Utrecht.—3rd, 5th. Utrecht.—8th. Tübingen.—9th, 10th, 13th, 29th, 30th. Utrecht.
 — May 2. Utrecht.
 — July 18. Utrecht.
 — Aug. 4, 8. Utrecht.—31st. Italy, Zwanenburg.
 — Sept. 5. Berlin.—6th. Utrecht.—10th. Utrecht, Wittenberg.—13th, 14th. Utrecht.—27th. Bologna, Utrecht, Zwanenburg, Schneeberg.—29th. (?).
 — Oct. 1. Utrecht, Zwanenburg.—2nd. Utrecht, Göttingen.—3rd, 5th. Utrecht.—9th. Utrecht, Göttingen.—19th. Portugal.—23rd. Tübingen.
 — Nov. 23, 24, 27. Steinbronnen.—28th. Utrecht.
 — Dec. 2. Plymouth, Steinbronnen.—3rd. Utrecht,

- Wittenberg, Berlin.—17th. Plymouth, Utrecht, Zwanenburg.—18th. Paris, Utrecht, Dantzic.—21st. Steinbronnen.—22nd. Utrecht.—23rd. Steinbronnen.—24th. Italy, Berlin.—26th. Steinbronnen.—27th. Utrecht.—29th, 31st. Steinbronnen.
1748. Jan. 2. Steinbronnen.—6th, 7th, 20th. Utrecht.—25th, 28th. Steinbronnen.—29th. Utrecht.
- Feb. 2. Plymouth.—3rd. Utrecht.—24th. Stuttgart.—27th. Utrecht, Zwanenburg, Berlin, Wittenberg.—28th, 29th. Zwanenburg.
- Mar. 1. Steinbronnen.—3rd, 5th. Utrecht.—28th, 29th. Stuttgart.
- April 1. Tübingen.—20th. Steinbronnen.—24th, 26th. Utrecht.—27th. Stuttgart.
- May 1, 2, 12, 21. Utrecht.
- June 3. Utrecht, Tübingen, Göttingen.—4th. Zwanenburg.
- July 17, 22. Utrecht.—27th. Berlin.
- Aug. 1. Utrecht.—29th. Göttingen.
- Sept. 6. Göttingen.—8th. Plymouth.—11th, 23rd. Utrecht.—27th. Steinbronnen.
- Oct. 12. Utrecht.—18th. Steinbronnen.—22nd, Bologna.
- Nov. 12. Berlin.—17th. Steinbronnen.—28th. Dantzic.
- Dec. 8. Denainvilliers, near Pithiviers.—14th. Dresden.—15th. Plymouth.—16th. Utrecht, Stuttgart.—18th. Utrecht, Berlin.—24th. Utrecht, Stuttgart, Berlin, Wittenberg.
1749. Jan. 10, 18. Utrecht.—20th, 21st. Stuttgart.—23rd. Utrecht.
- Feb. 2. Stuttgart.—9th. Zwanenburg, Berlin.—11th. Utrecht.—16th. Stuttgart.—28th (?).
- Mar. 6, 7. Utrecht.—10th. Stuttgart, Steinbronnen.—11th. Utrecht.—17th. Stuttgart.—18th. Plymouth, Stuttgart.—19th. Berlin.—21st, 23rd. Stuttgart.—28th. Utrecht.—31st. Stuttgart.
- April 2. Utrecht.—5th. Plymouth, Zwanenburg, Berlin.—7th. Plymouth, Stuttgart.—9th. Stuttgart.—10th, 12th. Göttingen.—14th, 16th. Stuttgart.—17th, 18th. Plymouth.—22nd. Stuttgart.
- May 3. Stuttgart.—9th. Plymouth.—10th. Utrecht, Göttingen.—12th. Plymouth.
- July 7. Plymouth.—8th, 9th, 11th, 12th. Utrecht.

1749. Aug. 15, 20. Utrecht.
 — Sept. 17. Bologna.—22nd. Rome, Bologna, Utrecht,
 Zurich, Tübingen, Steinbronnen, Leipzig.
 — Oct. 8. Bologna, Parma.
 — Nov. 16. Utrecht.
 — Dec. 4. Stoke (Gloucestershire).
 1750. Jan. 1. Zwanenburg.—3rd. Utrecht.—5th. Zwanen-
 burg.—6th. Denainvillers, Utrecht, Leipzig,
 Berlin, Wittenberg.—23rd. Tooting.
 — Feb. 3. Naples, Bologna; Toulouse, Paris; Chelsea,
 London, Cambridge, Norfolk, Norwich;
 Utrecht; Geneva, Boetterkinden, Zurich;
 Zwanenburg, Cologne, Hamburg, Hanover;
 Tübingen, Steinbronnen, Leipzig, Witten-
 berg, Berlin, Dantzig, Wotzlaw near Dantzig.
 —4th. Hamburg, Wittenberg, Berlin, Dant-
 zig.—5th. Breslau.—7th. Italy; Utrecht.—
 9th. Zwanenburg.—10th. Göttingen.—26th.
 Plymouth.—27th. Paris; Chelsea, Ply-
 mouth; The Hague, Utrecht; Zwanen-
 burg, Wittenberg, Dantzig.
 — Mar. 4. Utrecht; Zwanenburg, Tübingen, Stein-
 bronnen, Berlin.—9th. Utrecht.—11th.
 Utrecht; Leipzig.—12th. Saxony.
 — April 8. Bologna.—5th. Utrecht.—8th. Utrecht;
 Zwanenburg.—13th. Hamburg, Zwanen-
 burg, Berlin.—15th. Plymouth.—25th, 26th,
 28th. Utrecht.
 — May 1. Utrecht; Tübingen, Steinbronnen, Berlin.—
 2nd. Utrecht; Wittenberg.—3rd. Utrecht;
 Berlin.—4th, 6th, 7th, 8th, 22nd, 23rd.
 Utrecht.
 — June 2. Utrecht.
 — July 26. Utrecht; Zwanenburg, Leipzig.—27th.
 Utrecht.
 — Aug. 4, 5. Utrecht.—24th. Paris; Zwanenburg, Witten-
 berg, Berlin.—26th. Bologna, London,
 Utrecht; Zwanenburg, Tübingen, Dresden,
 Berlin, Dantzig.—27th. Bologna, Heilbronn.
 — Sept. 2. Utrecht.—4th. Berlin.—7th. Utrecht.—8th.
 Utrecht; Zwanenburg.—9th. Utrecht.—
 18th, 19th. Zwanenburg.—22nd. Plymouth,
 Leipzig.—23rd. Plymouth.—29th. (?).
 — Oct. 12. Northampton.—13th. Plymouth, Northamp-
 ton.—21st, 22nd, 26th. Plymouth.
 — Nov. 2. Zwanenburg.—4th. Plymouth.—9th. Tübingen.

1750. Dec. 14. Bologna, Utrecht.—19th. Göttingen.—26th. Utrecht.—28th. Zwanenburg, Tübingen, Steinbronnen, Göttingen.—31st. Tübingen.
1751. Jan. 8, 4. Utrecht.—19th. Plymouth.—24th. Utrecht.
- Feb. 3. Sheffield, Tooting.—11th. Tübingen, Steinbronnen, Göttingen.—19th. Paris, Wittenberg, Berlin.
- Mar. 1, 2, 9, 15, 16, 17, 19, 21, 31. Utrecht.
- April 2. Utrecht.—17th. Berlin.—19th, 21st. Utrecht.—25th, 26th. Berlin.
- May 18. Berlin.—22nd. Utrecht.—30th. Tübingen.
- July 28. Berlin.
- Aug. 19. Bologna, Plymouth, Zwanenburg.
- Sept. 3. Tübingen.—11th, 15th. Utrecht.—19th. Tübingen.—28th. Utrecht.—29th. (?)
- Oct. 19. Utrecht.—23rd. Plymouth, Zwanenburg, Tübingen, Steinbronnen.
- Nov. 30. Tübingen.
- Dec. 4. Berlin.—11th. Plymouth.—24th. Utrecht.
1752. Jan. 9. Utrecht.—18th. Tübingen.
- Feb. 26, 29. Tübingen.
- Mar. 2. Utrecht.—3rd. Utrecht, Zwanenburg.—6th. Tübingen.—7th. Utrecht.—8th. Göttingen.—18th, 21st, 22nd, 31st. Utrecht.
- April 2. Utrecht.—14th. Zwanenburg.—19th, 21st. Utrecht.
- May 6, 13. Tübingen.—17th. Stuttgart.—22nd. Utrecht.
- July 16. Tübingen.—21st. Stuttgart.—31st. Tübingen.
- Aug. 2. Tübingen.—4th. Stuttgart.—23rd. Tübingen.
- Sept. 11, 15, 28. Utrecht.—29th. (?)
- Oct. 2. Plymouth.—3rd, 4th, 5th. Zwanenburg.—12th. Denainvilliers, Zwanenburg, Berlin.—13th. Denainvilliers, Stuttgart, Berlin, Zwanenburg.—14th. Plymouth, Zwanenburg.—19th. Utrecht.—20th. Zwanenburg.
- Nov. 8. Zwanenburg.—17th. Tübingen.—30th. Plymouth.
- Dec. 5. Zwanenburg, Dantzig.—14th. Tübingen.
1753. Jan. 2. Utrecht.—23rd, 24th. Zwanenburg.
- April 7. Utrecht.—20th. Göttingen, Brocken (Harz).—24th, 27th. Utrecht.
- Aug. 27, 31. Utrecht.
- Sept. 3. Göttingen.—13th, 17th. Zwanenburg.—22nd. Utrecht.
- Oct. 11. Zwanenburg.
- Nov. 28. Utrecht.

1753. Dec. 80, 81. Utrecht.
1754. Jan. 11, 19, 22, 26, 27, 81. Utrecht.
- Feb. 1. Zwanenburg.—14th, 15th, 19th, 21st, 23rd, 27th. Utrecht.
- Mar. 18. Utrecht, Zwanenburg.—21st, 24th, 25th, 26th. Utrecht.
- April 12, 15, 16, 18, 19, 23. Utrecht.—27th. Zwanenburg.—28th. Utrecht.
- May 4. Zwanenburg.—8th, 9th, 16th, 17th. Utrecht.
- July 23. Utrecht.
- Aug. 14, 17, 19, 22, 23. Utrecht.
- Sept. 21, 24. Utrecht.
- Oct. 12, 16. Utrecht.—27th. The Hague.
- Nov. 14. Utrecht.
- Dec. 14, 18, 19. Utrecht.
1755. Jan. 6, 7. Venice.—15th. Utrecht.
- April 11, 12, 13, 14, 15. Utrecht.
- May 4, 5, 7, 15. Utrecht.
- July 15. Utrecht.
- Aug. 15, 17. Utrecht.
- Oct. 8, 10, 14. Utrecht.
- Dec. 20, 29. Utrecht.
1756. Jan. 20. Utrecht.
- Feb. 5. Utrecht.—15th. Berlin.
- Mar. 24. Utrecht.
- April 2. Utrecht.
- May 4, 7, 20. Utrecht.
- July 17. Utrecht.
- Aug. 1. Utrecht.
- Sept. 14, 17, 24. Utrecht.—25th. Berlin.—29th. Utrecht.
- Oct. 12. Utrecht.—25th. Berlin.—26th, 30th. Utrecht.
- Nov. 18, 20. Utrecht.
- Dec. 1, 24, 25. Utrecht.
1757. Feb. 20, 28. Utrecht.
- Mar. 10, 11, 17, 20, 25, 26, 27, 28. Utrecht.—81st. Rouen.
- April 1. Rouen.—14th, 18th, 21st, 23rd, 30th. Utrecht.
- May 13, 15, 16. Utrecht.
- Aug. 9, 12, 15, 16, 19. Utrecht.—26th. Dantzic.
- Sept. 1, 2. Utrecht.—16th. Utrecht, The Hague; Berlin.—18th. Utrecht.
- Nov. 12. London; Berlin.—17th. Utrecht.
- Dec. 6. Berlin (?).
1758. Jan. 7, 8, 9, 10. Utrecht.
- Feb. 2. Utrecht; Berlin.—12th, 18th, 14th, 25th. Utrecht.

1758. Mar. 13, 14, 29, 30. Utrecht.
 — April 2. Berlin.—13th. Utrecht.
 — May 2, 9, 10, 11. Utrecht.—28th. Zwanenburg.
 — July 27, 28, 29, 30. Utrecht.
1759. Jan. 20. Zwanenburg.
 — Feb. 4. London; Berlin.—5th. London.—8th. Paris.—20th. Rouen.
 — Mar. 23. London; Zwanenburg.
 — April 5. Zurich, Wödensweil.—25th. Zwanenburg.
 — May 11. London.
 — July 28. Zwanenburg.
 — Sept. 16. Rouen, Yvetot; London; Hanover, Göttingen, Zwanenburg.—28th. London.
 — Oct. 2, 8, 31. London.*
 — Nov. 23. Zwanenburg.—28th. London; Zwanenburg.
 — Dec. 23. London.
1760. July 20. Hanover.
 — Aug. 26. Zurich.
1761. Feb. 21. Vienna.—28th. Erlangen; Tyrnau (Hungary).
 — Nov. 18. Berlin.—19th. Zurich; Berlin.
1762. Mar. 21. Paris.
 — May 21. Paris.
1763. Jan. 14. (?)
 — Mar. 23. Lausanne.
 — Oct. 12. Warsaw.—16th. Eisenach, Gotha, Erfurt; Warsaw. — 17th. England; Eisenach, Gotha, Erfurt, Berlin; Warsaw.
1764. Mar. 4. London.—5th. Lisbon; Oxford.
 — April 17. Berlin.—23rd. Oxford.
 — Sept. 29, 30. Posen.
1765. Jan. 11. Denainvilliers.
 — Mar. 19. Denainvilliers.
 — Sept. 2. Denainvilliers.
 — Oct. 9. Denainvilliers.—12th. Paris.—18th. Denainvilliers.
1766. Oct. 12. Oxford.
1767. Feb. 6. Kiel.
 — Mar. 11. Kiel.
 — April 18. Environs of Paris.
 — Aug. 5. Kiel.
 — Dec. 13. Lucques.
1768. Feb. 15, 18. Riel.
 — May. 3. Plymouth.—4th. Plymouth, Bridgwater; Kiel.—5th. Plymouth, Bridgwater.—24th. Plymouth.
 — Aug. 6. Paris; Kiel.

1768. Oct. 28. Rome; Gurzelen; Vienna; Bœringen (Württemberg); Berlin.
 — Dec. 5. Paris, Denainvilliers, Nanteuil; Gurzelen; Vienna; Bœringen, Göttingen, Berlin.—6th. Normandy.—10th. Kiel.
1769. Jan. 2. Berlin.—5th. Paris, Montmorency.—17th, 18th. Berlin.
 — Feb. 1, 12, 15, 18. Berlin.—24th. Château de Broglie (Normandy).—25th. Berlin.—26th. Courlain (Beauce); Oxford.
 — Mar. 4. Havre.—14th, 18th, 26th, 27th. Berlin.
 — April 18, 14, 17, 19, 20. Berlin.
 — May 27. Berlin.
 — Sept. 2. Between Paris and Bayeux.—9th. Oxford; Berlin.—21st. Oxford.—26th. Burgundy; Gurzelen; Vienna; Bœringen.
 — Oct. 2. Oxford.—24th. Beziers, Auch, Paris, Rheims, Havre; Vienna, Gruz; Lübeck, Kiel, Berlin.—25th. Paris, Havre; Kiel, Lübeck; Iena, Franecker.—26th. Paris. — 27th. Havre.
 — Nov. 8. Berlin.—17th. Iena.
 — Dec. 20. Denainvilliers.
1770. Jan. 17. Hanover, Kiel, Berlin.—18th. Cadiz, Spain; Naples, Rome, Genoa; Béziere, Burgundy; London; Debreczin, Vienne, Tyrnau; Aaspach, Bœringen, Iena, Lübeck, Kiel, Berlin.—24th. Kriegsheim (Rhenish Hesse).—27th. Denainvilliers.
 — Feb. 1. Berlin.—12th. Gurzelen; Berlin.—15th, 18th, 25th. Berlin.
 — Mar. 14, 18, 23, 26, 27. Berlin.—29th. Iena.
 — April 18, 14, 17, 19, 20. Berlin.
 — May 27. (?)
 — July 81. (?)
 — Aug. 1. Lübeck.—8th, 10th. Iena.—11th. (?).—28th. Paris, Honfleur.—30th. Béziere, Normandy.—81st. Conteville (Normandy); Göttingen, Berlin, Iena.
 — Sept. 9. Berlin.—17th. Burgundy, Paris, Montmorency; Gurzelen; Vienna; Bœringen, Lübeck.—20th. Bœringen.
 — Nov. 8. Lübeck.—17th. Environs de Paris.—26th. Lübeck.
 — Dec. 17, 24. Iena.
1771. Jan. 6, 15, 18, 20. Berlin.

1771. Feb. 9, 10, 15. Berlin.—18th. Sparendam.—19th. Montmorency; Franecker, Berlin.—20th. Montmorency.
- Mar. 6. Montmorency.—18th. Montmorency; Franecker; Gurzelen, Berlin.
- April 4. Berlin.—5th. Montmorency; Børingen; Berlin.—15th. Montmorency, Berlin.
- May 2, 3, 6, 7, 8. Berlin.—12th. Iena; Franecker.—13th. Gurzelen, Franecker.—28th. Franecker (?).
- June 2. Lübeck.
- July 12. Berlin.
- Aug. 3. Berlin.—5th. (?)—29th. Franecker.
- Oct. 5, 6. Berlin.—9th. Berlin, Franecker.
- Nov. 1. Franecker.—12th. Berlin.—18th. Denainvillers.—14th. Franecker.—18th. Berlin.
- Dec. 5. Franecker.
1772. Jan. 1, 3. Berlin.
- Feb. 6. Berlin, Franecker.—18th. Marseilles.
- Mar. 2, 3. Franecker.—5th. Wittenberg, Berlin.—6th. Montmorency.—7th, 8th, 9th. Franecker.—22nd. Berlin.—28th. Berlin, Franecker.—30th. Berlin.
- April 3. Berlin, Franecker.—20th, 25th. Berlin.—29th. Franecker.
- June 14. Marseilles.—21st, 22nd. Franecker.—(?) two auroras seen in June in the south of England. Dates not given.
- July 18. (?)
- Aug. 6. (?)—11th. Franecker.—31st. Montmorency; Berlin.
- Sept. 1. Franecker.—20th. Berlin.—25th, 27th. Franecker.
- Oct. 2. Montmorency; Brussels; Franecker.—5th. Marseilles.—6th. Brussels.—14th. Marseilles; Franecker.—16th, 20th. Franecker.—23rd. Marseilles; Franecker.—26th. Montmorency.—27th. Ancona, Padua, Piedmont; Marseilles, Montmorency; Gurzelen, Vienna; Børingen; Iena, Berlin.—29th, 30th. Franecker.—31st. (?)
- Nov. 10. (?)—15th. Marseilles.—24th. Børingen; Berlin.—27th. Berlin.
- Dec. 3. Marseilles.—18th. Berlin.—20th. Marseilles.—24th. Montmorency.
1773. Jan. 16. Børingen, Zutphen.—17th. Børingen; Berlin.—18th. Franecker; Berlin.—19th. Berlin.

- 21st. Franecker; Berlin.—23rd. (?).—
24th. Gurzelen.
- 1773. Feb. 1. Franecker.—18th, 20th, 21st. Franecker, Ber-
lin.—22nd. Berlin.—27th. Børingen.
- Mar. 12. Berlin, Franecker.—13th. Børingen, Fra-
necker.—14th. Berlin, Franecker.—15th.
Paris.—16th. Franecker.—21st. Berlin.
—23rd. Franecker.—26th. Montmorency;
Franecker, Berlin.
- April 17. Franecker.—20th. Brussels; Franecker.—27th.
Franecker.
- May 9. Børingen.—11th. Marseilles.—13th, 17th,
18th, 19th. Berlin.—24th, 26th. Marseilles.
- June 24, 29. Franecker.
- July 17, 25. Franecker.
- Aug. 13. Lemgo (Lippe).—15th, 16th. Breslau.—18th.
Berlin.
- Sept. 1. Marseilles.—11th. Montmorency; Franecker.
—12th. Franecker.—15th. Berlin.—22nd,
24th. Marseilles.—27th. Denainvilliers;
Franecker,
- Oct. 7. Berlin, Franecker.—8th, 15th. Berlin.—19th.
Brussels, Franecker.—20th. Montmorency;
Brussels; Børingen; Franecker.—21st.
Franecker, Børingen.—27th, 28th. Fra-
necker.
- Nov. 7. (?).—8th. Børingen.—17th. Franecker.
- Dec. 13. Franecker.—15th. Marseilles; Børingen,
Franecker.
- 1774. Jan. 10. Franecker.—11th. Børingen, Franecker.—
12th. Franecker.—15th, 30th. Børingen.
- Mar. 2. Berlin, Franecker.—3rd. Montmorency; Brus-
sels; Franecker; Berlin.—13th. Franecker;
Berlin.—14th. Montmorency; Buxton, Ken-
sington; Brussels; Franecker; Berlin.—
15th. Montmorency; Brussels; Franecker.
—17th. Franecker; Berlin.—18th, 20th,
26th. Franecker.—30th. Berlin.—31st.
Franecker; Berlin.
- April 1. Berlin.—4th. Franecker; Berlin.—6th, 7th.
Berlin.—23rd. Brussels.
- May 1, 2. Marseilles.—3rd. Brussels; Franecker.—5th.
Marseilles; Franecker.—10th. Franecker.
—14th. Cologne.—16th. Brussels.—23rd,
30th. Franecker.
- June 6, 7, 12. Lübeck.—13th. Marseilles.—15th. Lübeck.

1774. July 10. Marseilles.—18th. Franecker.—14th. Marseilles.—24th, 25th. Franecker.
 — Aug. 1, 2, 8. Franecker.—21st. Lübeck; Franecker.—22nd. Marseilles; Franecker.—27th, 28th. Marseilles.—29th. Franecker.
 — Sept. 8, 19. Franecker.—25th, 26th, 30th. Montmorency.
 — Oct. 1. Berlin.—6th. The Hague.—8th. Sparendam.—12th. Berlin.—21st. Franecker.—27th. Berlin.—28th, 29th. Franecker.
 — Nov. 8, 5, 11, 80. Franecker.
 — Dec. 1. Marseilles; Børingen, Berlin.—2nd. Børingen.—4th. Marseilles.—26th. Sparendam.
1775. Jan. 2. Montmorency.—3rd, 4th. (?)—6th. Franecker.—20th, 21st. Montmorency; Franecker.—23rd, 24th. Franecker; Berlin.—25th. Franecker.—28th. Montmorency; Franecker.—30th. Berlin.
 — Feb. 1, 4. Brussels.—19th. Franecker.—20th. Bordeaux.—21st, 28th. Franecker.
 — Mar. 1, 19, 20, 21, 26, 27, 28, 29, 30. Franecker. Two auroras were seen this month at Berlin; dates unknown.
 — April 4, 18, 15, 17, 18. Franecker.—19th. Louvain; Franecker.
 — May 1. Berlin (?)—2nd, 15th. Franecker.—19th. The Hague.—20th. Franecker.
 — July 20, 21. Franecker.
 — Aug. 4, 20. Franecker.
 — Sept. 5. Sparendam.—14th, 15th, 16th. Franecker.—17th. Montmorency, Franecker.—19th. Vire.—22nd, 23rd, 27th. Franecker.
 — Oct. 18. Brussels; Børingen.—19th, 20th. Berlin (?)—21st. Vienna; Sparendam.—24th, 25th. Franecker.—(?) Leeds.
 — Nov. 6. (?)—23rd. Franecker.
 — Dec. 15. Franecker, Berlin.—22nd. Berlin (?)—23rd. Hanover.—25th. (?)—26th. Sparendam, Hanover.—27th. Berlin (?).
1776. Jan. 18. Berlin.—20th. Hanover; Franecker.—21st. Franecker; Berlin.—23rd. (?)
 — Feb. 11, 17, 18, 19, 20. Franecker.
 — Mar. 12, 13. Montmorency.—26th. Holland—28th. Montmorency.
 — April 8. Montmorency; Brussels; Franecker; Berlin (?)—10th. Brussels.—14th. The Hague.—19th. Franecker.

1776. May 8. Brussels.—21st. Franecker.—23rd, 25th. Brussels.
- June 6, 7. Brussels.
- July 7. Franecker.
- Aug. 14. Montmorency; The Hague, Sparendam; Franecker.—19th, 20th. Berlin (?).—26th. Franecker.
- Sept. 8, 4. Franecker.—5th. Montmorency; Franecker; Berlin.—6th, 12th. Franecker.—16th. Bordeaux, Montmorency; Brussels; Franecker; Børingen.—17th. Berlin (?).—22nd. Montmorency; Brussels, Breda, The Hague.—23rd. Montmorency; Brussels; Franecker.—24th. Franecker.—25th. Brussels.
- Oct. 8. Franecker.—17th. Sparendam.—27th. Franecker.
- Nov. 16. Franecker; Berlin.
- Dec. 16. Franecker.
1777. Jan. 13. Montmorency.—28th. Sparendam, Franecker.—30th. Sparendam.
- Feb. 5. Montmorency; Sparendam.—6th. Sparendam.—7th. Montmorency; Sparendam.—17th. Sparendam.—26th. Limoges, Denainvilliers, Paris, Montmorency, Neufmoutiers en Brie, Caen, Havre, Montdidier, Nancy, Réthel, Mazarin, Cambrai, &c.: Breda, Amsterdam, Dordrecht, Middelburg, The Hague; Iena; Franecker; Berlin.—27th. Montmorency.
- Mar. 1. Berlin.—5th. Montmorency.—6th. Brussels, Breda, Sparendam; Franecker.—10th, 11th, 12th. Franecker.—18th. Berlin (?).—17th. (?).—22nd. Breda, Amsterdam; Franecker.—25th. Berlin (?).—28th. Berlin.—29th. Breda, Sparendam, Franecker; Berlin.—31st. Sparendam.
- April 1. Brussels.—4th, 5th. Brussels; Sparendam, Franecker, Berlin.—6th. Montmorency.—7th, 8th. Brussels; Franecker.—9th. Brussels, The Hague, Franecker; Berlin.
- May 4. Sparendam.—5th. Breda, Amsterdam, Sparendam, Leeuwarden, Franecker.—21st. Leeuwarden.—30th, 31st. Franecker.
- June 28. Franecker.
- Aug. 6. Franecker.—17th. Berlin.—24th. Breda, Franecker.—26th. Montmorency; Spa-

- rendam.—27th. Montmorency; Sparendam, Franecker, Børingen.
1777. Sept. 4. Berlin.—7th. Ile d'Oléron, Chinon, Brest, Saint-Malo, Montmorency; Breda, Franecker.—24th. Montmorency; Sparendam, Franecker; Berlin.—26th. Perpignan.—28th. Franecker.
- Oct. 8. Geneva.—8th, 10th. Franecker.—22nd. Sparendam, Franecker.—24th. Montmorency; Franecker.—25th. Franecker.
- Nov. 8. Bordeaux, Sarlat, Viviers, Montargis, Denainvilliers, Paris, Montmorency; Breda, Leeuwarden, Franecker; Vienna; Børingen, Iena, Berlin.—6th. Sparendam.—7th. Sparendam, Franecker.—9th. Sparendam.—21st. Breda, Sparendam, Franecker.—23rd. Sparendam.—27th. Bordeaux, Dijon, Montargis, Chinon, Montmorency, Strasbourg; Sparendam, Franecker; Børingen, Iena.
- Dec. 1. Sparendam; Berlin (?).—2nd. Sparendam.—3rd. Perpignan, Limoux, Toulon, Béziers, Viviers, Tarascon, Saint-Galmier, Dijon, Chinon, Paris, Montmorency, Strasbourg, Lucerne and almost all Switzerland; Vienna; Ratisbon, Nuremberg; Børingen, Iena, Berlin, Königsberg.—4th. Berlin.—5th. Montmorency, Berlin.—6th. Montmorency; Breda, Sparendam, Franecker; Vienna.—17th. Sparendam.—18th. Sparendam, Franecker.—27th. Mannheim.—31st. Chinon.
1778. Jan. 18. Franecker.—19th. Sparendam.—20th. Franecker, Sparendam.—21st. Montmorency, Franecker, Sparendam.—25th. Havre; Vienna; Ulm, Iena.—26th. Franecker, Sparendam.—27th. Sparendam.
- Feb. 16. Chinon, Saint-Malo; Franecker.—17th. Chinon, Saint-Malo.—19th. The Hague.—25th. Marseilles, Bordeaux, Tremblade, Poitiers, Montmorency, Havre; Breda, Sparendam; Børingen; Vienna.—26th. Chinon; The Hague, Sparendam.—28th. Saint-Malo.
- Mar. 10. Perpignan.—15th. Gurzelen.—17th. Béziers, Denainvilliers, Montmorency; Franecker, Sparendam; Børingen.—18th. Montmo-

- rency.—19th. Sparendam.—22nd. Breda, Franecker, Sparendam; Berlin.—25th. Berlin.—26th. Bordeaux, Chinon, Montmorency, Rouen, Cambrai; Breda, Franecker; Berlin.—27th. Franecker. Sparendam.—31st. Berlin.
1778. April 14. Switzerland; Iena.—17th. Berlin.—18th. Lucerne.—19th. Berlin.—21st. Breda, Sparendam.—23rd. Saint-Saturnin (Provence).—25th. Ile d'Oléron.—26th. Bœringen, Berlin.
- May 14. Franecker, Sparendam.—20th. Brussels.—22nd. The Hague.
- June 8. The Hague.—10th, 11th, 12th. Franecker.—26th. Havre.—28th. Cadiz; Senegal; Béziers, Paris, Montmorency, Dieppe; Franecker.
- July 8. Perpignan.—7th. Berlin (?).—9th. Padua; Bordeaux; Brussels, The Hague.—15th. Franecker.
- Aug. 12. Franecker.—18th. Berlin.—22nd. Brussels, Breda; Sparendam, Franecker.—28th. Brussels, Breda; Berlin.
- Sept. 15. Franecker.—17th. Montmorency; Franecker.—18th. Sparendam; Berlin.—19th. Viviers, Mur-de-Barrez, Rouergue.—20th. Mur-de-Barrez.—21st. Bordeaux, Mur-de-Barrez, Viviers, Dijon, Saint-Malo, Montmorency, Rouen; Sparendam; Bœringen, Iena.—22nd. Bordeaux, Tremblade, Châtel-lerault, Ile d'Oléron, Luçon, Dijon, Saint-Brieuc, Saint-Malo, Montmorency; Franecker; Vienna; Ulm; Iena.—23rd. Berlin (?).—24th. Viviers, Dijon, Bœringen.—27th. Sparendam.—28th, 29th. Franecker.—30th. Berlin.
- Oct. 9. Sparendam.—18th. Berlin (?).—14th. Ile d'Oléron, Montmorency, Rouen, Dieppe; Franecker, Sparendam; Berlin.—15th, 19th. Sparendam.—23rd. Franecker.—26th, 27th. Sparendam.
- Nov. 20. Franecker.—24th. Sparendam.
- Dec. 2. Montpellier.—7th. Sparendam.—8th. Franecker.—18th. Iena.—14th. Troyes, Montmorency.—15th. Sparendam.—17th. Franecker.—26th. Montmorency.

1779. Jan. 3. Breda.—6th. Brussels.—7th. Breda, The Hague, Børingen.—9th. Franecker.—10th. Brussels, Sparendam.—12th. Sparendam.—13th. Franecker, Sparendam.—14th. Saint-Saturnin.—19th. The Hague, Børingen.—21st. Ingolstadt.
- Feb. 4, 6. Leeuwarden, Franecker, Sparendam.—7th. Børingen.—9th. Spain; Nancy, Réthel, Cambrai; Brussels, Breda; Leyden, The Hague, Amsterdam, Sparendam, Franecker; Børingen.—10th. Spain; Bordeaux, Vienna (Dauphiné), Chinon, Denainvilliers, Réthel; Glarus; Børingen, Ingolstadt; Iena, Berlin.—11th. Viviers, Vienna, Montmorency; Franecker, Sparendam, Gurzelen; Børingen; Berlin.—12th. Vienna, Denainvilliers; Breda, Amsterdam, Sparendam, Franecker.—13th. Béziers, Tarascon, Rodez, Vienna, Nancy; Gurzelen, Basle; Vienna; Børingen, Iena, Berlin.—14th. Béziers, Marseilles.—15th. Perpignan, Béziers, Marseilles, Tarascon, Viviers, Rodez, Bordeaux, Ile d'Oléron, Chinon, Essarts, Montmorency, Rouen; Brussels, Franecker; all Switzerland, Børingen, Iena, Berlin.—16th. Berlin.—18th. Nancy.—19th. Dieppe.
- Mar. 1. Ingolstadt.—2nd. Franecker; Ploskow (Kiev).—14th. Spain; Mur-de-Barrez, Cusset, Nancy, Réthel; Gurzelen, Børingen; Vienna.—15th. Ratisbon.—20th. Amsterdam.—22nd. Børingen.—24th. Brussels; Franecker.—25th. Ile d'Oléron, Chinon, Montmorency, Rouen, Nancy, Réthel; Brussels; Breda, The Hague, Leyden, Amsterdam, Leeuwarden, Franecker; Børingen, Iena.—26th. Amsterdam.—30th. Montmorency; Amsterdam.—31st. Rodez, Montmorency.
- April 2. Nancy; The Hague.—3rd. The Hague; Berlin.—4th. Franecker.—6th. Berlin.—7th. Montmorency, Berlin.—8th. Brussels; Berlin.—9th. Brussels, Breda; Franecker, Sparendam; Berlin.—10th. Nancy; Børingen; Berlin.—11th. Essarts; Ratisbon.—13th. Viviers.—17th. Berlin.—18th. Brussels: Breda, Franecker; Bø-

- ringen.—19th. The Hague.—20th. Rome;
Brussels, Breda, The Hague, Amsterdam,
Sparendam, Franecker.—21st. Béziers,
Montmorency; Brussels, Breda, The Hague,
Amsterdam, Sparendam, Franecker.—22nd.
Nancy; Børingen.—28th. Brussels, Breda.
1779. May 2. Brussels.—4th, 6th, 7th, 8th, 10th. Berlin.—
11th. Montmorency; Berlin.—12th, 18th,
15th, 17th. Berlin.—20th. Denainvilliers,
Brussels.—24th. Rodez, Chinon, Denain-
villiers, Nancy, Dieppe; Breda, The Hague,
Leyden, Franecker, Sparendam.
- June 3, 5. Brussels.—6th. The Hague.—8th. Padua;
The Hague.—14th, 15th. Ile d'Oléron.—
20th. Montmorency.—24th. Ile d'Oléron.
- July 9. Bordeaux; Brussels, The Hague.—15th. Bor-
deaux; Brussels.—17th. Brussels.—20th.
Bordeaux.—27th. Brussels.
- Aug. 1. The Hague.—3rd. The Hague, Franecker.—
4th. Leyden.—14th. Rouen.—17th. Fra-
necker.—29th. Brussels.—28th. Franecker.
—29th. Montmorency; Sparendam, Fra-
necker.—30th. Nancy.
- Sept. 8. Sparendam.—10th. Franecker.—11th. Spa-
rendam.—17th. Saint-Saturnin, Vienna,
Cusset; Brussels.—18th. Padua; Béziers,
Marseilles, Tarascon, Viviers, Villefranche,
Vienna, Ile d'Oléron, Pontarlier, Nancy,
Montmorency; Franecker; all Switzerland,
Børingen; Iena, Berlin, Königsberg.—19th.
Mezin (Guienne); Iena.—22nd. Agde,
Strasbourg.—28th. Franecker.—29th.
Nancy.
- Oct. 3. Montmorency; Brussels, Breda, Sparendam.
—4th. The Hague, Franecker.—14th.
Cusset, Nancy, Montmorency; Brussels,
Breda; The Hague, Leyden, Amsterdam,
Sparendam, Franecker, Leeuwarden; Bø-
ringen.—17th. Nancy; Brussels, Breda,
The Hague, Franecker.—19th. Perpignan.
—20th. Brussels.—22nd. Sparendam.
- Nov. 7. Saint-Saturnin.—8th. Ile d'Oléron.—9th.
Perpignan, Saint-Saturnin, Béziers, Nantes,
Denainvilliers, Montmorency, Nancy; Brus-
sels; Breda, The Hague, Leyden, Amster-
dam, Sparendam, Franecker; Børingen;

- Vienna; Berlin.—10th. Leeuwarden.—12th. Luçon.—13th. Marseilles, Ile d'Oléron, Montmorency, Nancy; Brussels; Sparendam, Leeuwarden.—14th. Brussels, Berlin.—15th. The Hague, Leyden, Sparendam.—18th. Nancy.
1779. Dec. 5. Montmorency, Nancy; Brussels, Breda; Amsterdam, Sparendam, Franecker; Børingen; Vienna.—6th. Montmorency, Nancy; Brussels, Breda; The Hague, Leyden, Amsterdam. Sparendam, Leeuwarden, Franecker; Gurzelen.—8th. The Hague; Franecker.—9th. Iena.—10th. Brussels.—11th. The Hague, Franecker, Sparendam.—30th. The Hague.
1780. Feb. 11. Franecker, Sparendam.—22nd. Montmorency.—28th. Franecker.—29th. Spain; Padua, Turin; Béziers, Montmorency; Franecker; Gurzelen, Geneva, Berne, Lucerne; Børingen; Vienna; Iena; Königsberg.
- Mar. 1. Perpignan.—2nd. London; Franecker; Mannheim; Königsberg; Pleskov.—17th. Berlin (?).—29th. Montmorency.—30th, 31st. Chinon.
- April 2. Berlin (?).—4th. Berlin.—6th. Iena.—9th. Berlin.—12th. (?).
- May 5. Børingen.—7th, 8th. (?).—17th. Lucerne.—19th. (?).
- June 15. Montmorency.
- July 18. Montmorency.—20th. Lucerne.—25th. Børingen.—27th. The Hague.—28th. Como, Italy; Montmorency; Franecker; Geneva, Gurzelen, Berne; Børingen, Frankfort-am-Main, Karlsruhe, Göttingen, Iena, Berlin.—29th. Paris, Montmorency; Franecker.
- Aug. 15. Ratisbon.—26th. Franecker.
- Sept. 4. Franecker; Berlin.—3rd. Børingen.—4th, 5th. Franecker.—17th. Dantzic.—22nd, 27th. Montmorency.
- Oct. 6. Iena.—10th. Berlin.—30th. Rochelle, Viviers; Geneva; Franecker.
- Nov. 3. Montmorency.—4th. Berlin.—21st. Rochelle, Girard, Saint-Mauritz, Troyes, Franecker.—22nd. Sparendam.—24th. Børingen.—25th. Viviers, Rochelle, Girard, Saint-Mauritz, Troyes, Franecker; Geneva Gurzelen,

- Berne; Vienna; Børingen.—26th. Rochelle;
Franecker.—27th. Montmorency.
1780. Dec. 3, 5. Montmorency.—7th. Lucerne; Berlin.—19th.
Denainvilliers; Berlin.—30th, 31st. Trieste.
1781. Jan. 16. Franecker.—18th. Padua.—21st. Abtei St.
Zenonis.—28th. Mannheim.—30th. Padua,
Béziers, Montmorency; Lucerne; Vienna;
Munich, Peissenberg, Kloster Rott, Ratisbon;
Berlin; Sagan.—31st. Peissenberg.
- Feb. 5. Montmorency.—12th. Berne.—15th. Padua;
Béziers, Montmorency; Ratisbon; Berlin.
—16th. Mannheim.—18th. Berlin.
- Mar. 14. Franecker; Mannheim; Børingen, Kloster
Rott, Wurtemberg.—19th. Mannheim, Ber-
lin.—20th. Mannheim; Erfurt.—23rd.
Padua.—27th. Montmorency; London;
Franecker; Mannheim, Børingen, Ratisbon,
Erfurt.—28th. Montmorency; Mannheim,
Berlin.—29th. Montmorency; Mannheim,
Erfurt; Berlin; Sagan.
- April 1. Berlin.—4th. London.—14th. Mannheim.—
15th. Montmorency; Erfurt.—24th. Mann-
heim.—25th. Montmorency.
- May 4. Ratisbon.—11th, 14th, 16th, 18th. Berlin.
- June 6. Florence, Ratisbon.—8th. Mannheim; Ratis-
bon; Iena.—19th. Mannheim.—28th, 29th.
Ratisbon.
- July 6. Franecker.—8th. Mannheim.—17th. Sparen-
dam.—20th. Berlin.—22nd. Montmorency.
- Aug. 6. Franecker.—16th. Wurzburg.—21st. Mont-
morency; Mannheim.—23rd. Sagan.—25th.
Montmorency.—26th. Ratisbon, Mannheim.
- Sept. 2. Mannheim.—7th. Wurzburg.—8th. Mont-
morency.—9th. Wurzburg.—18th. Breda;
Erfurt, Berlin.—19th. Sagan, Berlin.—22nd.
Prague.—23rd. Paris, Montmorency; Børin-
gen, Iena, Erfurt.—24th. Montmorency;
Mannheim, Iena, Erfurt, Berlin.—25th. Mont-
morency; Slough; Breda, Amsterdam; Bø-
ringen; Berg St-Andex.—26th. Kloster Rott.
- Oct. 4. Mannheim.—14th. Prague.—15th. Padua;
Montmorency; The Hague, Franecker;
Børingen, Peissenberg, Ratisbon, Kloster
Rott; Sagan.—16th. Prague; Erfurt, Sagan.
—19th. Mannheim; Berlin; Sagan.—21st.
Sagan.—23rd. Padua.

1781. Nov. 8, 13. Sagan.—14th. Berlin.—15th. Erfürt, Berlin.—16th. Børingen.—18th. Sagan.—19th. Mannheim.—20th. Børingen.
- Dec. 10. Prague.—11th. Padua; Mannheim, Børingen; Iena; Berlin; Sagan.—12th. Wurzburg; Berlin.—13th. Berlin.—16th, 19th, 22nd. Erfürt.
1782. Jan. 4. Prague.—5th. Mannheim.—7th, 8th. Børingen.—9th. Mannheim; Sagan.—10th, 12th. Mannheim.—17th. Berlin (?).
- Feb. 2. Berlin (?).—3rd. Erfürt, Berlin.—14th. (?).—15th. Tegernsee.—16th. Tegernsee; Prague.—17th. Tegernsee.—18th. Franecker.—21st. Franecker; Tegernsee.—22nd. Tegernsee.—25th. Bologne; Béziers; Amsterdam; Prague.—26th. The Hague.
- Mar. 5. Franecker.—6th. Berlin (?).—9th. The Hague; Mannheim; Sagan.—10th. Prague, Sagan; Berlin.—15th. Montmorency; Mannheim; Sagan; Berlin.—17th. Børingen; Berlin.—27th. Berlin (?).—31st. Ratisbon.
- April 1. Berlin (?).—4th. Franecker.—6th. Børingen.—9th. Lucerne.—10th. Børingen.—13th. Berlin (?).—22nd. Franecker.—27th. Montmorency.—29th, 30th. Berlin (?).
- May 5. Mannheim.—7th. Padua; Montmorency.—8th. Berlin (?).—8th. Mannheim.—16th, 18th. Vienna.—20th. Berlin.—23rd. Berne.
- June 4. Padua.—5th, 13th. Mannheim.
- July 20. Mannheim.—31st. Padua.
- Aug. 2. Berlin (?).—30th. Slough.
- Sept. 2. Brussels, The Hague.—6th. The Hague; Sagan.—10th. Mannheim.—12th. Padua; The Hague; Mannheim; Berlin.—13th. The Hague; Mannheim; Ratisbon; Prague.—15th. Brussels.—30th. Rochelle, Montmorency; Brussels; Mannheim.
- Oct. 1. Montmorency; Brussels; Ingolstadt; Sagan, Erfürt; Berlin.—2nd. Berlin (?).—3rd. Montmorency; Sagan.—8th. Rochelle; Brussels, Franecker; Mannheim; Peissenberg; Buda; Berlin.—9th. Montmorency; Middelburg; Ratisbon; Berlin.—12th. The Hague.—17th. Berlin.
- Nov. 7. Rochelle.—20th. Franecker.
- Dec. 31. Sagan.

1783. Jan. 9. Dijon—18th. Franecker; Mannheim.—80th. Erfurt.
- Feb. 12. Tegernsee.—19th. Breslau.—28th. Lübeck.
- Mar. 4. Franecker; Lübeck; Erfurt, Sagan.—16th. Berlin.—18th. Padua.—20th. Iena.—21st. Leeds; Sagan.—22nd. Prague.—24th. Padua.—25th. Sagan.—26th. Slough; Franecker.—27th, 28th. North Germany.—29th. Montmorency; Franecker; Mannheim, Fürstenfeld, Bavaria; Sagan, North Germany.—80th. Rochelle; Gurzelen; Mannheim, Düsseldorf; Sagan, Erfurt; Berlin; North Germany.—81st. Rochelle; Franecker; North Germany.
- April 2. Amsterdam; Mannheim.—3rd. Sagan.—7th. Padua; Franecker; Middelburg; Mannheim.—9th Brussels; Berlin.—12th. Leeds; Prague; Iena, Berlin.—14th. Erfurt.—18th. Berlin.—20th. Fürstenfeld.—21st. Franecker; Fürstenfeld; Sagan.—22nd. Mannheim.—25th. Brussels; Franecker; Sagan.—26th. Montmorency; Leeds; Middelburg; Mannheim; Erfurt; Sagan.—27th. Padua; Rochelle, Dijon, Paris, Montmorency; Franecker, Middelburg; Düsseldorf, Mannheim, Ratisbon; Prague; Göttingen, Erfurt; Berlin, Sagan.—28th. Middelburg; Ratisbon; Prague.—29th. Paris, Montmorency; Franecker, Middelburg; Mannheim; Prague; Göttingen, Iena, Erfurt; Berlin, Sagan.—80th. The Hague; Mannheim, Fürstenfeld (Bavaria).
- May 1. Iena; Sagan.—3rd. Prague; Sagan, Berlin.—4th. Mannheim.—5th. Mannheim; Prague.—12th. Montmorency; Brussel.—16th. Montmorency; Mannheim.—17th. Brussels.—21st. Berlin.—22nd. Montmorency, Laon.—29th. Mannheim; Ratisbon.
- June 1. Padua.—2nd. (?).—3rd. Erfurt.—19th. Lausanne.
- July 2. Ratisbon.—28th. Karlsruhe; Göttingen.—30th. Mannheim.
- Aug. 1. Franecker; Mannheim; Ratisbon.—8th. Prague.—9th. Ratisbon.—19th. Berlin.—28th. Northampton.

1788. Sept. 4. Mannheim.—15th. Montmorency, Laon.—
25th. Middelburg; Prague.—26th. Fra-
necker; Middelburg.
- Oct. 22. Montmorency, Laon; Middelburg; Buda;
Peissenberg; Sagan, Erfurt; Berlin.—23rd.
Montmorency, Laon.—24th. Rochelle.—
26th. Dijon.—27th. Berlin.—29th. Montmo-
rency, Laon; Prague.—31st. Montmorency,
Laon.
- Nov. 3. Mannheim.—11th. Andex.—13th. Mannheim.
—14th. Montmorency, Laon.—15th. Dijon.
—26th. Iena.
- Dec. 3. Berlin (?).—4th. Mannheim.—17th. Berlin.—
18th. Prague.
1784. Jan. 10. Prague.—11th. Padua.—20th, 21st. Rochelle.
- Feb. 23. London, Kimbolton, Cambridge, Kensington.
—25th, 26th. Hildesheim.
- Mar. 5. Mannheim.—12th. Ratisbon.—13th, 14th.
Mannheim.—15th, 18th. Sagan.
- April 9. Ratisbon.—10th. Mannheim.—16th, 18th. Ber-
lin.—21st. Padua.
- May 6. Peissenberg.—9th. Laon.—12th. Paris; Mann-
heim.—17th. Paris; Delft; Erfurt, Iena.—
22nd. Paris.
- June 16, 17. Rochelle.—21st. Ratisbon.—30th. Saint-
Véran.
- July 1. Saint-Véran.—3rd. Delft.—16th. Mannheim.
—24th. Berlin.—25th. Padua; Paris; Mann-
heim; Geneva.—26th. Mannheim.
- Aug. 4. Prague.—5th, 15th. Berlin.
- Sept. 6. Sagan.—8th. Mannheim.—11th, 12th. Sagan.
—15th. Middelburg, Delft; Mannheim;
Furstenfeld, Bavaria; Prague; Iena, Sagan.
—18th. Berlin (?).
- Oct. 4. Rochelle.
- Nov. 15. Padua; Dijon, Paris, Laon; Dusseldorf;
Mannheim; all Bavaria; Prague; Sagan,
Erfurt, Berlin.
- Dec. 31. Sagan.
1785. Jan. 17. Berlin.—26th, 28th. Tegernsee.
- Feb. 3. Tegernsee.—16th, 17th, 22nd. Mannheim.
- Mar. 8. Vienna.—6th. Sagan.—22nd. Paris.
- April 3. Brussels.—12th, 27th. Mannheim.—29th. Ro-
chelle; Berlin.
- May 1, 15. Brussels.—23rd. Paris.
- June 28. Mannheim.
- July 3, 17. Brussels.—24th. Mannheim.

1785. Aug. 8. Brussels.—9th. Padua; Berlin.—11th. Brussels.
—80th. Mannheim.—31st. Middelburg.
- Sept. 13. Brussels.—20th. Berlin.—23rd. Mannheim.
- Oct. 4. Sagan; Berlin.—5th. Mannheim; Iena.—6th.
Middelburg.—7th. Sagan.—12th. Berlin.—
22nd. La Rochelle.
- Nov. 2. Laon; Brussels; Sagan, Erfurt; Berlin.—5th.
Brussels; Mannheim; Berlin.—6th. Sagan.
—29th. Mannheim; Sagan; Berlin.—30th.
Sagan.
- Dec. 13. Mannheim.—19th. Berlin.
1786. Jan. 4. Prague.—14th. Mannheim.—18th. Brussels.—
30th. Tegernsee.
- Feb. 17. Sagan; Berlin.—20th. Berlin.—28th. Brussels;
Berlin.
- Mar. 19. Paris; Vienna; Prague.—20th. Erfurt.—21st.
Vienna; Sagan.—22nd. Rome; Padua;
Marseilles; Brussels; Berne, Sutz, Zurich;
Buda; Munich, Berg Sankt-Andex, Peissen-
berg, Tegernsee, Ratisbon; Prague;
Sagan.—23rd. Buda; Sagan.—25th. Mar-
seilles; Mannheim; Berlin.—26th. Sagan.—
28th. Marseilles.—29th. Marseilles; Berne;
Sagan.—31st. Sagan.
- April 2. Sagan; Berlin.—3rd. Brussels.—18th. Padua;
Brussels, Delft; Ratisbon; Sagan, Erfurt,
Iena; Berlin.—19th. Sagan.—20th. Brus-
sels; Mannheim; Sagan.—21st. Sagan.—
22nd. Mannheim; Ratisbon, Wurzburg;
Sagan, Berlin.—23rd. Brussels; Mannheim;
Sagan.—24th, 25th. Sagan; Berlin.—26th.
Peissenberg; Prague; Sagan; Berlin.—
27th. Sagan.—29th. Brussels, Delft; Ratis-
bon; Prague; Sagan.—30th. Delft.
- May 1. Paris; Kendal; Brussels; Berlin.—2nd. Brus-
sels, Delft; Berlin.—3rd. Brussels; Berlin.
—4th. Berlin.—5th. Brussels.—8th. Berlin.
—11th. Kendal; Berlin.—12th. Brussels.—
14th. Paris; Berlin.—15th. Brussels;
Prague; Berlin.—16th, 17th. Brussels.—
18th. Brussels; Berlin.—19th, 20th. Brus-
sels.—22nd. Rome; Kendal; Brussels.—
24th. Padua; Berlin.—30th. Montmorency;
Sagan.—31st. Rochelle, Paris, Montmo-
rency; Delft; Berlin.
- June 4. Delft.—5th. Mannheim.—28th. Delft.—30th.
Brussels.

1786. July 5. Paris.—13th. Paris; Kendal.—15th. Kendal.—18th. Berlin.—20th, 22nd. Brussels.—24th. Brussels; Berlin.—25th. Montmorency.—29th. Prague.
- Aug. 2, 8. Brussels.—11th. Kendal.—16th. Brussels.—17th. Kendal.—18th. Montmorency; Brussels.—19th. Brussels.—21st. Brussels; Mannheim.—27th. Mannheim.
- Sept. 3, 5. Mannheim.—8th. Kendal.—19th. Paris; Kendal; Delft; Mannheim; Berlin.—20th. Kendal; Sagan.—21st, 26th, 29th. Kendal.
- Oct. 2. Rome.—10th. Mannheim.—12th. Sagan.—18th. Padua; Paris; Kendal; Delft; Mannheim; Sagan, Erfurt.—14th. Padua; Mannheim.—16th. Mannheim.—17th. Brussels, Delft, Middelburg; Mannheim; Sagan.—18th. Brussels.—22nd, 23rd. Sagan.—25th. Padua; Kendal; Prague; Iena; Berlin.—28th. Sagan.
- Nov. 5. Berlin (?).—8th. Paris.—12th. Mannheim.—14th. Kendal.—20th. Mannheim.
- Dec. 2. (?).—3rd. Mannheim.—5th, 18th. Brussels.—20th. Middelburg.—25th. Kendal.—28th. Tegernsee.
1787. Jan. 7. Mannheim.—9th. Rochelle.—12th. Kendal.—21st. Bologna; Mannheim; Sagan.—22nd. Montmorency; Mannheim; Prague; Sagan, Erfurt, Göttingen.—24th. Kendal.—25th. Paris; Kendal.—27th. Prague.—29th. Mannheim.
- Feb. 6. Berlin (?).—15th. Bologna, Padua; Paris.—16th, 17th. Wurzburg.—18th. Sagan.—22nd. Kendal.—25th. Mannheim; Prague; Berlin.—27th. Prague.
- Mar. 2. Mannheim.—16th. Mannheim; Sagan.—17th. Mannheim.—18th. Paris; Mannheim; Munich; Buda.—19th. Peissenberg.—20th. Paris.—21st. Rochelle, Paris; Kendal; Berne; Mannheim; Munich, Peissenberg, Ratisbon; Göttingen, Erfurt, Sagan.—22nd. Ratisbon.—24th. Kendal; Mannheim.—26th. Mannheim.
- April 1. Rochelle; Sagan.—2nd. Rochelle; Mannheim; Ratisbon; Göttingen, Erfurt, Iena.—6th. Sagan.—12th, 13th. Bologna.—16th. Sagan.—17th. Mannheim.—18th. Padua.—19th.

- Padua; Rochelle; Kendal; Mannheim, Göttingen, Erfurt, Sagan.—20th. Rochelle; Kendal; Mannheim.—22nd. Rochelle.—23rd. Mannheim.—26th. Kendal; Iena.
1787. May 4. Göttingen.—10th. Rochelle.—11th. Ratisbon.—12th. Kendal; Erfurt.—13th. Rome, Padua; Marseilles, Vienna, Rochelle, Paris, Laon; Buda; Munich, Ratisbon; Prague; Sagan, Iena, Ronneburg.—14th. Padua; Rochelle, Paris.—15th. Rochelle.—16th. Paris; Kendal.—17th. Rome; Rochelle; Kendal.—18th. Paris; Kendal.—19th. Paris; Peissenberg; Erfurt.—21st. Mannheim.—25th. Montmorency.—27th. Berlin (?).—29th. Rochelle.
- June 5. Rochelle.—6th. Prague.—7th. Rochelle; Kendal.—8th. Paris.—10th. Montmorency.—21st. Rome.—24th. Mannheim.
- July 11. Erfurt.—13th. Rome, Bologna, Padua; Marseilles, Vienna, Rochelle, Paris, Montmorency, Laon; Berne; Mannheim; Buda; Göttingen, Erfurt; Sagan; Berlin.—14th. Bologna, Padua; Göttingen.—16th. Bologna.—20th. Mannheim.—22nd. Mannheim; Sagan.—30th. Göttingen; Berlin.
- Aug. 8.—Prague.—7th. Paris; Kendal; Ratisbon; Erfurt, Iena.—10th. Paris.—11th. Berlin (?).—19th. Kendal; Mannheim.—21st. Paris.—24th. Berlin (?).—25th, 30th. Mannheim.
- Sept. 6. Bologna; Paris; Middelburg; Göttingen; Sagan.—7th. Paris; Mannheim; Iena.—8th. Mannheim.—10th. Sagan.—19th. Kendal.—23rd. Mannheim.—26th. Prague.—28th, 30th. Mannheim.
- Oct. 1. Sagan.—4th. Kendal; Iena, Sagan.—5th. Rome, Bologna; Mannheim; Prague; Munich, Sankt-Andex, Ratisbon, Wurzburg; Göttingen, Erfurt, Iena, Sagan.—6th. Rome, Bologna, Padua; Marseilles, Paris, Montmorency; Mannheim; Berne, Zurich, Geneva; Buda; Prague; Munich, Peissenberg, Tegernsee, Sankt-Andex, Ratisbon, Wurzburg; Göttingen, Erfurt, Iena, Sagan.—7th. Padua; Kendal; Ratisbon.—10th. Berne; Buda; Munich, Peissenberg, Tegernsee, Ratisbon, Wurzburg; Sagan.—13th.

- Padua; Rochelle, Paris; Berne, Sutz, Geneva; Buda; Prague; Göttingen, Erfürt, Sagan, Berlin.—14th. Göttingen, Berlin.—16th. Rochelle.—17th. Marseilles, Rochelle, Paris; Kendal; Berne, Geneva; Prague; Göttingen; Sagan, Berlin.—19th. Kendal.—20th. Berlin.—21st. Peissenberg.—24th. Ratisbon; Buda; Iena; Sagan.—31st. Rochelle, Paris; Mannheim; Berne, Geneva; Buda; Prague; Munich, Tegernsee, Sankt Andex, Ratisbon, Wurzburg; Erfürt, Iena, Sagan.
1787. Nov. 2. Sagan.—3rd. Prague.—4th. Kendal; Göttingen; Berlin.—7th. Sagan.—8th. Rome; Paris, Caen, Laon; Kendal; Mannheim; Berne, Sutz, Geneva; Munich, Tegernsee, Peissenberg, Ratisbon; Prague; Erfürt; Sagan.—9th. Brussels; Mannheim; Sankt Andex; Prague; Sagan.—10th. Mannheim.—12th. Wurzburg.—18th. Mannheim.—20th. Wurzburg.—21st. Montmorency.—26th. Rome; Rochelle, Paris, Montmorency; Mannheim; Berne, Sutz; Ratisbon; Göttingen; Erfürt, Sagan.—28th. Kendal.—29th. Kendal; Berlin.—30th. Kendal.
- Dec. 6. Rochelle.—9th. Paris.—10th. Mannheim; Sagan.—15th. Sagan.—16th. Berne.
1788. Jan. 3. Sagan.—4th. Mannheim.—5th, 8th. Sagan.—9th. Kendal; Mannheim.—10th. Kendal, Keswick.—11th. Kendal; Mannheim; Peissenberg.—18th. Kendal.—14th. Kendal; Sagan.—15th. Kendal.
- Feb. 2. Sagan.—4th. Kendal; Sagan; Berlin.—6th, 7th. Keswick.—8th. Kendal.—9th. Sagan.—11th. Spain; Padua; Rochelle, Montmorency; Brussels, Middelburg; Mannheim; Geneva; Buda; Munich, Peissenberg, Tegernsee, Ratisbon; Erfürt, Iena; Sagan, Berlin.—12th. Keswick.—15th. Rome; Buda; Erfürt, Iena.—22nd. Mannheim.
- Mar. 7. Rome; Kendal, Keswick; Sagan.—8th. Kendal; Sagan.—14th, 22nd. Mannheim.—27th. Brussels.—28th. Paris; Kendal; Mannheim.
- April 1. Paris, Montmorency; Kendal.—2nd. Montmorency; Geneva.—3rd. Kendal; Sagan.—4th. Brussels.—6th. Sagan; Iena.—7th.

- Kendal.—10th. Ratisbon.—14th. Kendal.—21st. Mannheim.—23rd. (?)—24th, 26th. Sagan.—27th. Montmorency; Kendal; Sagan.—28th. Kendal, Keswick; Brussels.—29th. Paris; Kendal; Ratisbon.—80th. Paris; Kendal.
1788. May 1. Kendal.—2nd. Paris.—3rd. Brussels.—4th. Kendal.—7th. Brussels.—10th. Kendal; Brussels.—11th. Kendal.—24th. Padua; Paris, Montmorency; Kendal, Keswick, Dublin; Brussels; Mannheim; Geneva.—25th. Paris; Kendal; Brussels; Mannheim.—26th. Brussels; Ratisbon.—27th. Kendal.
- June 8. Kendal.—4th. Padua.—5th, 9th. Brussels.—25th. Brussels; Iena.—27th, 28th. Brussels.
- July 1. Brussels.—2nd. Mannheim.—3rd. Paris.—5th. Iena.—10th. Brussels.—14th. Mannheim.—15th. Saint-Gothard.—80th. Paris; Kendal; Berne; Ratisbon.—81st. Iena.
- Aug. 1. Rochelle; Kendal.—2nd, 3rd. Kendal.—11th. Mannheim.—19th. Kendal, Keswick; Iena.—20th. Rome.—23rd. Rome; Paris; Kendal, Keswick; Mannheim; Geneva.—24th. Mannheim.—27th. Iena.—28th. Iena, Sagan.—29th. Kendal; Mannheim; Wurzburg; Iena, Sagan.—31st. Iena, Sagan.
- Sept. 1. Brussels; Sagan.—2nd. Kendal; Berne, Geneva.—3rd. Erfurt, Iena.—4th. Paris; Brussels; Mannheim; Ratisbon; Iena, Sagan.—5th. Rome, Padua; Mannheim; Berne, Sutz; Munich, Tegernsee, Ratisbon, Wurzburg; Erfurt, Iena, Sagan.—6th. Kendal; Wurzburg; Erfurt.—7th. Wurzburg.—10th. Kendal; Iena.—12th. Mannheim.—19th. Munich.—24th. Spain; Mannheim; Tegernsee; Erfurt, Sagan, Iena.—27th, 29th. Sagan.
- Oct. 11. Kendal; Mannheim.—12th. Paris; Sagan.—13th. Paris.—18th. Sagan.—21st. Spain; Marseilles; Kendal; Mannheim; Geneva; Buda.—22nd. Spain; Rome; Padua; Marseilles, Béziers, Rochelle; Mannheim; Geneva; Buda; Erfurt, Iena, Sagan.—24th. Kendal.—24th. Kendal.—25th. Sagan.—26th. Geneva.—27th. Kendal, Keswick;

- Sagan.—28th, 29th. Sagan.—30th. Kendal ;
Sagan.—31st. Paris, Laon ; Kendal.
1788. Nov. 1. Kendal ; Geneva.—2nd. Geneva ; Sagan, Erfurt.—3rd, 18th. Sagan.—19th. Kendal.—23rd. Paris ; Mannheim ; Sagan.—26th. Sagan.—27th, 28th, 30th. Kendal.
- Dec. 8, 15, 16. Mannheim.—20th. Peissenberg.—21st. Kendal, Keswick.—23rd. Paris ; Brussels ; Berne ; Ratisbon ; Sagan.—24th. Kendal.—30th. Mannheim.
1789. Jan. 11. Kendal.—19th. Sagan.—21st. Mannheim.—22nd. Berlin (?).—24th. Sagan.—29th. Paris ; Sagan.—30th. Sagan.
- Feb. 2. Mannheim.—4th. Paris.—15th. Keswick ; Berne.—20th. Sagan.—23rd. Kendal ; Sagan.—24th. Paris.—25th. (?).—26th. Kendal ; Mannheim.—28th. Kendal.
- Mar. 8. Paris.—14th. Paris ; Kendal, Keswick ; Brussels ; Sagan.—16th. Kendal.—20th. Mannheim.—22nd. Sagan.—27th. Rome ; Marseilles, Paris. Montmorency ; Brussels ; Mannheim ; Berne, Sutz, Geneva ; Ratisbon ; Prague ; Iena.—28th. Rochelle ; Brussels ; Mannheim ; Berne, Sutz, Ratisbon ; Sagan.—29th. Marseilles ; Kendal ; Brussels ; Sagan.—30th. Kendal ; Brussels ; Sagan.
- April 12. Kendal.—18th. Kendal, Keswick.—17th. Brussels.—19th, 20th, 27th. Sagan.—29th. Mannheim ; Sagan.—30th. Kendal.
- May 15, 16. Brussels.—17th. Paris ; Mannheim.—23rd. Paris ; Ratisbon.—24th. Ratisbon.—28th, 29th. Brussels.—31st. Sagan.
- June 2, 4. Paris.—10th. Ratisbon.—12th. Paris ; Kendal.—18th, 16th, 19th, 21st. Ratisbon.—24th. Paris ; Ratisbon.—30th. Brussels.
- July 15. Brussels.—16th. Paris.—18th, 19th, 20th, 23rd. Brussels.—24th. Paris.—28th. Laon.—29th. Brussels.
- Aug. 13. Keswick.—14th. Kendal ; Sagan.—15th. Paris ; Kendal.—16th, 18th. Kendal.—19th. Kendal ; Berne ; Peissenberg ; Prague ; Sagan.—20th. Kendal.—24th. Paris.—25th. Paris ; Keswick ; Ratisbon, Sagan.
- Sept. 14, 15. Kendal.—17th. Brussels.—20th. Kendal, Keswick ; Sagan.—21st. Brussels.—23rd. Kendal.—24th. Sagan.—25th. Brussels ;

- Berne, Sutz ; Mannheim.—26th. Rochelle,
Paris, Falaise, Laon ; Kendal, Keswick ;
Brussels ; Berne ; Peissenberg ; Mannheim.
—27th. Sagan.—30th. Paris.
1789. Oct. 18. Kendal.—19th. Marseilles ; Kendal, Geneva.
—20th. Paris ; Kendal ; Brussels ; Peissen-
berg ; Iena ; Sagan.—21st. Brussels.—23rd.
Kendal, Keswick.—25th, 27th, 31st. Kendal.
- Nov. 4. Kendal.—8th. Peissenberg.—10th. Kendal.—
14th. Béziers ; Kendal, Keswick ; Sagan.
—15th. Sagan.—18th. Brussels.—19th.
Kendal, Keswick.—20th. Sagan.—21st.
Kendal, Keswick.—22nd. Kendal ; Sagan.
—24th, 25th, 26th, 27th. Kendal.
- Dec. 10. Sagan.—14th. Kendal ; Sagan.—15th, 16th,
19th. Sagan.—20th. Peissenberg.—22nd.
Mannheim ; Sagan.—24th. Paris.
1790. Jan. 6. Paris.—9th, 10th. Sagan.—14th. Kendal.—
18th. Mannheim ; Sagan.—29th. Laon ;
Mannheim ; Prague ; Iena, Sagan.
- Feb. 1. Sagan.—3rd. Kendal.—4th. (?)—9th. Kendal.
12th, 13th. Sagan.—14th. Mannheim.—
15th. Sagan.—17th. Brussels.
- Mar. 2. Mannheim.—8th. Brussels ; Peissenberg.—
10th. Kendal.—11th. Sagan.—16th. Ken-
dal ; Ratisbon ; Sagan.—17th. Kendal ;
Sagan.—18th. Kendal ; Mannheim.—19th,
20th. Kendal.
- April 2. Mannheim.—3rd, 4th. Kendal ; Mannheim.
—5th. Kendal.—6th. Kendal ; Mannheim.
—7th. Kendal.—8th. Mannheim.—9th.
Kendal ; Sagan.—11th. Mannheim.—16th,
17th. Kendal.—30th. Brussels.
- May 12, 14. Kendal.—16th. Kendal ; Peissenberg ;
Prague, Sagan.—18th. Kendal.—24th.
Brussels.—28th. Mannheim.—30th. Prague.
- June 3. Brussels.—4th. (?)—5th, 8th. Brussels.—22nd.
Peissenberg.—25th. Mannheim.
- July 13. Iena.—16th. Sutz, Switzerland ; Prague.—
28th. Pavia (?).
- Aug. 3. Mannheim.—8th. Paris.—19th. Berne (?).
- Sept. 9, 24. Sagan.—30th. Brussels ; Mannheim ; Sagan.
- Oct. 1. Mannheim.—4th. Sagan.—9th. Kendal, Mann-
heim.—14th. Mannheim.—18th, 31st.
Kendal.
- Nov. 4, 5, 6. Sagan.—7th. Kendal.—8th. Kendal ;

- Sagan.—9th. Kendal; Mannheim.—10th.
 Kendal.—12th. Kendal; Sagan.—16th.
 Kendal.—26th. Sagan.—27th. Kendal, Kes-
 wick.—28th, 30th. Kendal.
1790. Dec. 25. Kendal.—26th. Paris.—28th. Kendal.—30th.
 Sagan.
1791. Jan. 6. Padua; Kendal, Keswick; Brussels; Sagan,
 Berlin.—7th, 9th. Sagan.—20th, 25th.
 Mannheim.—28th, 29th. Sagan.
- Feb. 21. Ratisbon.—24th. Sagan.—25th. Kendal.—
 27th. Sagan.
- Mar. 2. Sagan.—3rd, 5th. Kendal.—7th. Kendal,
 Keswick.—20th. Mannheim.—26th, 29th.
 Kendal.
- April 3. Kendal.—5th. Sagan.—18th. Mannheim.—
 18th, 20th, 23rd, 25th. Kendal.
- May 5. Padua.—12th, 20th. Kendal.—23rd. Brussels.
 —26th. Brussels; Mannheim.
- June 10. Kendal.—19th. Sagan.—26th. Brussels.
- July 7. Mannheim.—20th. Brussels.
- Aug. 8. Paris.—18th, 20th. Mannheim.
- Sept. 5, 8, 11, 13. Kendal.—15th. Mannheim.—27th.
 Kendal.—28th. Kendal; Brussels.
- Oct. 6. Sagan.—15th, 19th, 20th. Kendal.—21st.
 Brussels.—22nd. Kendal, Keswick; Brus-
 sels.—23rd. Kendal; Sagan.—28th. Prague.
 —29th, 31st. Kendal.
- Nov. 3. Kendal, Keswick.—4th, 5th. Kendal.—8th.
 Mannheim.—11th, 14th. Kendal.—16th.
 Sagan.—17th. Kendal.—18th. Kendal;
 Brussels.—19th. Sagan.
- Dec. 18, 19. Kendal.—23rd. Brussels.—26th. Kendal;
 Brussels.—27th. Sagan.—28th, 29th.
 Brussels.
1792. Jan. 9. Kendal.—16th. Sagan.—17th. Kendal.—18th.
 Kendal; Sagan.—25th. Sagan.—30th.
 Brussels.
- Feb. 9, 17. Kendal.
- Mar. 2. Kendal.—4th. Berg Sankt Andex.—15th.
 Kendal.—16th, 19th, 25th. Sagan.—27th,
 31st. Mannheim.
- April 10. Montmorency; Kendal, Keswick; Sagan;
 Isserstædt.—11th. Kendal, Keswick; Sagan.
 —12th. Sagan.—13th. Mannheim.—14th.
 Sagan.—16th. Kendal; Mannheim.—17th.
 Brussels.

1792. May 6. Kendal.—8th. Brussels.—9th, 14th. Sagan.—
15th. Mannheim.—20th. Brussels.—22nd.
Montmorency.—27th. Brussels.
- June 2. Sagan.—29th. Kendal.
- July 16. Peissenberg.—19th. Brussels.
- Aug. 1. (?)—2nd. Sankt Andex.—4th. Kendal.—16th.
Sankt Andex.—23rd. Kendal.
- Sept. 1, 6, 14. Mannheim.—22nd. Kendal.—28th. Mann-
heim.
- Oct. 12. Kendal.—18th. Marseilles; Kendal, Keswick;
Brussels; Isserstædt; Sagan.—14th, 15th,
16th, 17th. Sagan.—18th. Kendal; Sagan.
—23rd, 31st. Kendal.
- Nov. 13, 14. Sagan.—19th. Kendal, Keswick.
- Dec. 7. Keswick.—12th. Padua.—30th. Sagan.
1793. Jan. 11, 12, 13. Kendal.
- Feb. 8. Kendal.—12th, 15th. Kendal, Keswick.
- Mar. 4. Paris.—5th, 6th. Kendal.—13th, 30th. Ken-
dal, Keswick.
- April 5. Kendal.—9th. Kendal, Keswick.—14th. Kes-
wick.
- May 27. Montmorency.
- June 9. Montmorency.
- Aug. 26. Montmorency.
- Nov. 8. Isserstædt.
1794. Jan. 7, 22. Manchester.
- Mar. 8, 29. Manchester.
- April 30. Paris, Montmorency.
- Dec. 7. Viviers, Paris.—8th. Paris; Manchester.—
19th. Manchester.
1795. Sept. 8, 14. Manchester.
- Oct. 16, 17. Paris.—18th. Manchester.
- Dec. 16, 17. (?)
1796. Jan. 15. Montmorency.
- April 6. Isserstædt.
- May 22. Paris.
1797. Jan. 22. Manchester.
- Feb. 1, 18, 17, 28. Manchester.
- Mar. 1. 2. Manchester.—10th. Yorkshire.
- April 24. Manchester.
- June or July (messidor, year V) 3. Records of auroras
without date at Montmorency.
- Nov. 18, 21, 22, 23. Manchester.
- Dec. 20. Manchester.
1798. Jan. 15. Montmorency.
- Sept. 26. (?)

1799. Feb. 25. Eckwarden.
 — July 24. Paris.
 — Sept. 8. Harrogate.—4th. Paris.
 — Oct. 25. Manchester.
 1800. Mar. 18. Manchester.
 — Aug. 15, 18. Paris.
 — Nov. 2, 7. Manchester.
 — Dec. 10. Manchester.
 1801. Jan. 4, 25. Manchester.
 — Feb. 22. Manchester.
 — Mar. 9. (?).
 — Oct. 6. Manchester.
 1802. Feb. 8. Manchester.
 — Mar. 29. Manchester.
 — June 8. Ratisbon.
 — Sept. 27. At sea, off Liverpool.
 — Dec. 18. Manchester.
 1803. Mar. 19. Paris.
 — April 12, 13. Manchester.
 — Sept. 11, 17. Manchester.
 — Oct. 12. Manchester.
 — Dec. 8. Manchester.
 1804. Feb. 2. Manchester.
 — Mar. 29. Paris.
 — April 1, 4. Manchester.
 — May 2. Manchester.
 — Oct. 12. Schnepfenthal.—22nd. Paris; England;
 Bruges; Prague, Bohemia; Halle, Iena;
 Schnepfenthal, Breslau, Berlin; Königs-
 berg.—23rd, 24th. Iena.
 — Nov. 22, 25. Manchester.
 1805. Jan. 1. Manchester, Carlisle.
 — Feb. 28. Manchester.
 — Mar. 26. Carlisle.
 — April 30. Manchester.
 — May 27, 28. Carlisle.
 — Sept. 21. Carlisle.—22nd. Carlisle; Berne.—23rd. Car-
 lisle.—24th. Paris; Manchester, Carlisle.
 — Oct. 13, 20, 21. Carlisle.—22nd. Manchester.
 — Nov. 16, 18, 19, 20, 25, 26. Carlisle.
 — Dec. 26. Carlisle.
 1806. Feb. 7. Manchester.
 — Sept. 12. Manchester.
 — Nov. 2. Manchester; Eckwarden.—30th. Zurich.
 — Dec. 20. Berlin.
 1807. Jan. 13. Halle.—26th. Dantzig.

1808. Mar. 25. Manchester.
 1809. No aurora borealis recorded this year within the prescribed limits.
 1810. Oct. 5. Ratisbon.
 1811-1812. No aurora in these two years within the prescribed limits.
 1813. June 24. Augsburg.
 — Sept. 24. Augsburg.
 1814. April 7. Tottenham; Berne.—15th. Ratisbon.—17th. Tottenham, England.
 — May 22. Ratisbon.
 — Sept. 10. Manchester.—11th. Manchester, Kendal.
 1815. Mar. 2. Ratisbon.
 — May 29. Ratisbon.
 1816. May 17. Ratisbon.
 — Sept. 15. Manchester.
 1817. Jan. 8. Berne.
 — Feb. 6. Paris.—8th. Paris; Sunderland and many parts of England; Berne, Hofwyl, Saint-Gall; Augsburg; Prague; Halberstadt, Leipzig.—9th. Königsberg.—10th. Ratisbon.—18th. Hamm; Prague.—20th. Walthamstow.
 — Mar. 4. Karlsruhe.—5th. Gordon Castle, Glasgow.
 — June 12. Ratisbon.
 — Aug. 16. Ratisbon.
 — Sept. 19. Gosport.
 — Oct. 17. Gosport.
 1818. Jan. 11. Prague and many parts of Bohemia.
 — Feb. 5. Gordon Castle.
 — April 4. Ratisbon.
 — Oct. 26. Sunderland.—31st. Bishopswearmouth (Sunderland).
 1819. Feb. 1. Paris.—23rd. Prague.
 — Mar. 12. Prague.
 — April 19. (?).—26th. Ratisbon.
 — Oct. 6. Zurich.—7th. Flensburg.—12th. Manchester.—15th. Suffolk.—17th. London and neighbourhood, Gosport, Manchester, Kendal, Keswick, Seathwaite.—31st. Gosport.
 — Dec. 14. London, Manchester.
 1820. Jan. 14. London, Stratford.
 — Feb. 9. Paris (?).—11th. Manchester.
 — Sept. 6. (?).
 — Nov. 20. Paris.

1820. Dec. 4. England.
 1821. Mar. 25. Gosport.
 — Nov. 26. Manchester.
 — Dec. 12. Manchester.
 1822. July 12, 17. Paris.
 1823 No aurora recorded for this year within the prescribed limits.
 1824. Nov. 16. Königsberg.
 1825. Oct. 7. Paris.
 — Nov. 7. (?).
 1826. Jan. 5. Königsberg.
 — Mar. 29. Carlisle, Doncaster, Kendal, Keswick, Manchester, Preston, Penrith, Warrington, Whitehaven.
 — April 29. Paris, Carlisle.
 — Aug. 29. (?).
 — Sept. 17, 18. (?).
 — Oct. 26, 27. (?).
 1827. Jan. 9. Paris; Kendal.—18th. Manchester, Gosport.
 — Feb. 13. Gosport.—17th. Manchester, Gosport.
 — Aug. 13. (?).—25th. Paris, Saint-Cloud.
 — Sept. 8. Saint-Cloud; Berlin.—9th. Many parts of England.—25th. Paris, Havre, Arras, Doullens; Kendal, England; Ostend, Holland; Aarau, Zurich, Saint-Gall; Stuttgart, Munich, Bavaria; Prague, Arcona, Apenrade.—26th. Gosport; Berlin, Stettin; Apenrade.—28th. Paris.
 — Oct. 6. Manchester; Allerly.—17th. Gosport.
 — Nov. 18. Gosport, Allerly.—19th. Allerly.
 — Dec. 27. Kendal.
 1828. June 2. Yorkshire.
 — July 5. Montmorillon.—12th, 17th. (?).
 — Sept. 8. Prague.—20th. Chesterfields Lodge near Stevenage.—25th. Gosport.—29th. London, Gosport, Kendal, Manchester, Lynn Regis, Penzance, Boreham, Essex, Smedley Hall, Chesterfields Lodge.—30th. Plymouth, Gosport.
 — Oct. 1. Gosport.—9th. Manchester.—31st. Paris (?).
 — Dec. 1. Manchester, Wicksworth (Derbyshire).—20th. (?).—22nd. Crumpsall Hall (Manchester).—26th. Hull, Gosport, Manchester, Crumpsall Hall.—28th. Crumpsall Hall.
 1829. Jan. 2. Manchester.
 — Feb. 11. Berlin.

1829. Mar. 4, 6. Crumpsall Hall.—22nd. Crumpsall Hall,
Biggleswade.—29th. England.
- April 8. Dieppe.
 - May 2. Paris.—4th. Crumpsall Hall.
 - June 1. Paris.—7th. (?)—17th. Crumpsall Hall.
 - July 25. Kendal, Crumpsall Hall, Manchester.
 - Aug. 1. (?)—25th. Kendal.
 - Sept. 19. Crumpsall Hall, Manchester.—21st. Paris.
 - Oct. 2. Kendal.—3rd. Crumpsall Hall, Manchester.—
17th. Manchester.—25th. Kendal.—80th.
Paris.
 - Dec. 14. London, Gosport.
1830. Jan. 28. Kendal.
- Feb. 19. Kendal.—20th. Gosport.
 - Mar. 18. Manchester.
 - April 19. Manchester, York, and many parts of England.
—24th. Manchester, Leeds.
 - May 19. England.
 - Aug. 20. Kendal, Crumpsall Hall.
 - Sept. 7. Gosport, Manchester, Bedford, Isle of Man.
 - Oct. 5. Gosport, Kendal, Carlisle, Bedford, on the
Atlantic, on 42° 20' lat. N., and 89° 29' long.
W.—9th. Cambridge.—16th, 17th. Gos-
port.—20th. London.—22nd. Manchester,
Crumpsall Hall.
 - Nov. 1. Gosport, Boston, Bedford, Crumpsall Hall.—
8rd. Kendal.—4th. Gosport, Bedford,
Crumpsall Hall.—7th. Gosport, Bedford.—
10th. Crumpsall Hall.
 - Dec. 7. Marburg; Warsaw.—11th. Gosport, Bedford;
Neckarthal (Wurtemberg).—12th. Gosport,
Falmouth, Crumpsall Hall.—13th. Gosport,
Bedford.—14th. Gosport, Bedford; War-
saw.—22nd. Ackworth, Yorkshire.—25th.
Gosport, Kendal, Manchester, Smedley Hall.
—20th. Kendal.
1831. Jan. 5. Crumpsall Hall.—6th. Gosport, Manchester.
—7th. Madrid; Trieste; Paris, Versailles,
Strasbourg; Gosport, Bedford, Woolwich,
Blackheath, Falmouth, &c.; Brussels,
Maastricht, Utrecht; Geneva, Basle, Zurich;
Vienna; Munich, Botzen, Augsburg,
Bayreuth; Brunswick, Wurzburg, Marburg,
Elberfeld, Bernburg, Gotha, Leipzig;
Breslau, Salzuffeln, Berlin, Colberg, Königs-
berg; Angerburg; Brakel; Cracow; War

- saw.—8th. Woolwich, Bedford, Falmouth, Gosport, Crumpsall Hall; Wurtemberg.—10th. Falmouth, Crumpsall Hall.—11th. Kendal, Gosport, Bedford, Falmouth, Heron Court.—14th. Falmouth; Atlantic.—15th, 16th. Atlantic.—21st. Manchester.
1831. Feb. 11. Manchester, Crumpsall Hall.—14th. Crumpsall Hall, Lancaster.—15th. Falmouth.—17th. Falmouth, Lancaster.—(?). Benac, near Rennes.
- Mar. 6. Crumpsall Hall.—7th. Crumpsall Hall, Heron Court; Buchholtz near Frankfort-sur-Oder.—8th. Manchester, Gosport.—11th. Manchester, Marsden, Gosport, Lancashire.—12th, 13th. Crumpsall Hall.
- April 3. Crumpsall Hall.—19th. Manchester, Gosport; Berlin.—20th. Gosport; Berlin, Kitzingen.—23rd. Manchester.
- May 30. Gosport.
- July 14. (?).—20th. Gosport.
- Aug. 3, 5. Rome.—7th. (?).—12th. Paimbœuf.—26th. Basle.—30th. Augsburg.
- Sept. 12. Manchester, Gosport.
- Oct. 29. Manchester, Gosport. — Several auroras at Kendal in September and October, precise dates not given.
- Nov. 8. Wurtemberg.
- Dec. 9, 22. Paris.
1832. Jan. 14, 15, 16. (?).—27th. Manchester.
- Feb. 2. Giengen (Wurtemberg).—(?). Paris (?).
- Sept. 17. Cambridge, Manchester and district, York, Dent near Kendal, Armagh.—23rd. Manchester, Smedley Hall.
- Oct. 12. England.
- Nov. 1. Manchester, Bradford, Burnley, Kendal, &c.—4th. Lincoln.
- Dec. 21. Newcastle upon Tyne; Allerly.
1833. Feb. 11. Manchester.—18th. Crumpsall Hall.—19th. Manchester.
- Mar. 13. Cambridge.—21st. Manchester; observ. of Armagh, Athboy (Ireland).
- Aug. 6. Crumpsall Hall.
- Sept. 1. Carlisle.—14th. York, Greta-Bridge.—15th. Burn.—17th. London, Cambridge, York, Gosport, Manchester, Ireland.—18th. Manchester.

1833. Oct. 19. Paris; Cambridge, Manchester, York, Heron Court, Guisborough, Dent, Armagh.
 — Nov. 12. Brussels.
1834. Jan. 5. Catterick Bridge (Yorkshire).—15th. Brussels.
 — Feb. 10. Augsburg.—20th. Kendal.
 — June 28. Brussels.
 — July 8. (?).
 — Sept. 21. (?).
 — Nov. 8. England.
 — Dec. 21. England.—22nd. Woolwich; Braunsberg (eastern Prussia), Königsberg.
1835. Jan. 4. Augsburg.
 — Feb. 7. England; Göttingen; Braunsberg, Germany.—27th. Braunsberg.
 — July 8. (?).
 — Nov. 16. Woolwich.—17th. Paris; London, Ashurst, Dulwich and many parts of England; Hanover; Berlin.—18th. Nîmes, Cahors, Paris, Caen, Corbigny, Cherbourg; London, Chiswick, Greenwich, Woolwich, Oxford, Banbury, Deal, Collumpton; Armagh, Ireland; Brussels; Oldenburg.—19th. Paris.
1836. April 22. Channel Islands; High-Burns near Sunderland.
 — May 15. Sunderland.—20th. Paris.—24th. (?).
 — Aug. 10. Ryde.
 — Sept. 29. Dublin.
 — Oct. 5. Dublin.—11th. Dublin, Leominster; Zurich; Braunsberg.—12th. Zurich; Braunsberg.—18th. Spain; Parma, Forlì, Turin; Cahors, Chambéry, Paris, Strasbourg, Caen, Cherbourg, Corbigny, Rennes, Nantes; London, Londonderry and many parts of England; Brussels, Liege; Aix-la-Chapelle, Elberfeld, Cologne, Dusseldorf, Mayence; Wiesbaden, Karlsruhe; Stuttgart, Frankfurt-on-Mein; Zurich, Basle, Geneva; Innsbrück; Prague; Osnabrück, Hanover, Göttingen; Dresden; Berlin, Swinemunde, Colberg, Braunsberg, Danzig, Heiligenbeil, Elbing, Königsberg; Lamberg; Warsaw.—19th. Zurich.
 — Nov. 15. Brest.—27th. Hanover.
1837. Jan. 25. Basle, Zurich, nearly all Switzerland; Stuttgart, Giengen, Bubach.—26th. Giengen.—27th. Mecklin.

1837. Feb. 2. (?)—13th. Zurich; Königsberg and district.
 —14th. Zurich.—18th. Rome, Forlì, Pise,
 Venice, coast of Istria, Parma, Milan;
 Marseilles, Montpellier, Paris, Meaux, Luz-
 arches, Versailles, Beauvais, Morlaix, Sar-
 reguemines; London, Devonshire, Kent,
 Belfast, Sidmouth, Athurst; Zurich, Basle,
 Geneva; Prague; Stuttgart, all Swabia;
 Cologne, Nuremberg; Göttingen, Gotha,
 Halsbruck, Gnadenfeld (Silesia).
 — Mar. 29. Zurich, Switzerland.
 — April 6. Angiers; Breslau.—7th. Munich.
 — May 2. Breslau.—19th. England.
 — June 24. England.
 — July 1, 2, 7. England.—28th. Mannheim, Stuttgart;
 Vienna.
 — Aug. 4. Naples.—25th. England.
 — Sept. 22. Brussels.—23rd. Hamburg.—29th. Dublin.
 — Oct. 6. Paris.—11th. England.—18th. Parma; Paris;
 Geneva, Zurich, Switzerland; Bamberg,
 Hildburghausen, &c., and all Germany;
 Warsaw.—19th. Geneva.—21st. Warsaw.
 —22nd. Atlantic 40° 22' lat. N. and 38°
 54' long. W.
 — Nov. 5. Paris, Brest, Ushant; London; Leipzig.—
 12th. Parma, between Genoa and Leghorn;
 Montpellier, Angiers, Vendôme, Jambles
 near Givry, Paris, Athurst, Dulwich, &c.,
 England; Brussels; Aix-la-Chapelle; Basle;
 Prague; Augsburg, Würzburg; Kirchheim
 (Hesse), Hildburghausen, Gotha, Hanover;
 Berlin, Stettin.—14th. Paris, Jambles near
 Givry, Brest; Basle; Augsburg; Hanover;
 Cracow.—15th. Paris, Brest.
1838. Jan. 6. (?)—29th. Stuttgart, Wurtemberg.
 — Feb. 18. England.
 — April 29. Brussels.
 — Sept. 13. Paris; Athurst, Dulwich.—15th. Paris.
 — Nov. 12. Slough; Bremen; Eutin.—13th. Paris.
1839. Jan. 2. Milan.—6th. Parma.—10th. Hamburg and
 in the north.—12th, 14th. Parma.—17th.
 Brussels.—18th. England.—19th. Chiswick,
 Athurst, Dulwich, Dublin; Brussels.
 — Feb. 21. Eutin.
 — May. 5. France; England; Brussels.—7th. Parma,
 Saint-Brice near Ecouen.

1839. Aug. 30. Warsaw.
 — Sept. 1. Zurich.—3rd. Turin, Alexandria, Asti; Paris;
 London, Athurst, Dulwich; Brussels; many
 parts of Wurtemberg; Göttingen.—25th.
 (?).
 — Oct. 16. Douai.—22nd. Madeira; Rome, Pesaro;
 Marseilles, Aix, Toulouse, Paris, Meaux,
 Commercy, Strasbourg, Renac near Rennes;
 Brussels; Geneva; Stuttgart and many
 places in Wurtemberg; Berlin, Eutin.—
 23rd. Eutin.
 — Nov. 1. Eutin.—12th. Prague.
 — Dec. 14. Gosport.
 1840. Jan. 3. Huggate; Geneva; Halle.—11th. Geneva.
 — Feb. 6. Cracow.—17th. Einsiedeln, Switzerland.—
 25th. Brussels.
 — Mar. 11. (?).
 — April 24. Dublin.
 — May 29. Paris.
 — June 27. Parma.
 — July 5, 22, 23. Parma.
 — Aug. 8. Ghent.—19th. Prague.
 — Sep. 21. Parma; Brussels, Ghent, Groningen, Fra-
 necker; Cracow.
 — Oct. 9. Parma.—18th. Franckfort-on-Mein.—19th.
 Parma.—21st. Paris.—22nd. Parma.—
 20th. Parma; Brussels.
 — Nov. 7. Greenwich.—12th. Paris.—14th, 24th, 28th.
 Parma.
 — Dec. 11. Brussels.—14th. England.—21st. Brussels,
 Ghent, Groningen, Franecker; Eutin;
 Cracow.—24th, 28th. Parma.
 1841. Jan. 8. Greenwich.—24th. Brussels. Two auroras
 were seen this month at Eutin; dates not
 given.
 — Feb. 24. Brussels.
 — Mar. 10. Greenwich.—22nd. Greenwich, Durham,
 York, Belfast, England.
 — April 12. Greenwich.—15th. Prague.
 — June 15, 16, 21. Brussels.
 — Aug. 2. Prague.—10th. Parma.—23rd. Brussels.
 — Sept. 10. Paris, Prague.—12th, 18th. Prague.—23rd.
 Brussels.—25th. Parma, Brussels.
 — Oct. 14. Prague.—18th. Geneva.—25th. Prague.
 — Nov. 11. Paris.—15th. Prague.—18th, 19th. Brussels.
 — Dec. 1. Genoa, Prague.—6th, 8th. Greenwich, Cam-

- bridge.—12th. Paris.—15th. Prague.—
19th, 20th. Cracow.—24th. Prague.
1842. Jan. 2. Parma.
— Feb. 28. (?)
— Mar. 7. Guastalla.—10th. Greenwich.
— June 11. Genoa.—30th. Brussels.
— July 8. Brussels.
— Sept. 6. Gratz.
— Oct. 7. Montpellier.—16th. Parma.—17th. Geneva.—
18th. Brussels, Geneva.
— Nov. 4. France.—19th. (?)—24th. Paris.
1843. Jan. 2. Hamburg.
— Mar. 2, 8. Hamburg.—13th. Parma.—22nd. Brussels.
— April 5. Ghent, Hamburg.—6th. Brussels.
— May 6. Paris, Rheims, Dieppe; Greenwich, Colling-
wood; Brussels.—9th. Brussels.
— Aug. 2. Hamburg.
— Dec. 8, 10, 12. Parma.—29th. Paris.
1844. Jan. 12, 13, 19. Hamburg.
— Feb. 20. Hamburg.
— April 17. Hamburg.
— June 24. Paris (?).
— Aug. 1. Whitehaven.—9th. Hamburg.—22nd (?).
— Nov. 14. Hamburg.
— Dec. 8. Parma.—29th. Paris, Rheims.
1845. Jan. 6. Nantes.—10th. Hamburg.
— Mar. 6. Ulm.
— April 25. (?).
— July 6. (?).
— Aug. 25. Parma.—29th. Huggate, Bilk, near Dussel-
dorf.—30th. Between Dusseldorf and
Cologne.
— Sept. 1. Drachenfels.—24th, 25th, 26th. Bilk.
— Nov. 5. Parma.
— Dec. 8. Nottingham, Manchester; Eutin.—4th. Am-
sterdam, Bonn.—13th. Swansea.—14th.
Bonn.—29th. Rheims.
1846. Jan. 4. London.
— Feb. 18. Bonn.—25th. Geneva.
— Mar. 14. Geneva.
— Aug. 28. Bonn.
— Sept. 18. Huggate.—21st. Cambridge, Durham, Esk
near Durham, Bembridge, Isle of Wight.—
22nd. Paris, Rheims; Huggate; Bonn;
Breslau; Saatz (Bohemia).
— Oct. 17. Dublin.—24th. Monteagle (Ireland).

1846. Nov. 8. Paris.—11th, 13th. Bonn.—17th. Kingston, Bonn, Prague, Ukermark, Elberfeld, Leipzig. Many places in North Germany, and a few in South Germany.—18th. Brussels.—21st. Bonn.
- Dec. 11. Bonn, Rolandseck. — 13th. Bonn. — 16th. Yorkshire; Bonn.—17th. Bonn.
1847. Jan. 13, 14, Bonn.
- Mar. 17. Eutin.—19th. Greenwich, Hyde Vale, Cambridge, Playford near Ipswich, Darlington, Spalding, Wolverton, Norfolk; Brussels, Emden, Hamburg, Oldenburg, Leipzig.
- June 6. Brussels.
- Sept. 17. Paris.—21st. Norwich, Esk near Durham.—24th. North of France; Greenwich, Shropshire.—26th. Carlisle.—28th. Louviers.—29th. Carlisle, Swansea, Westmoreland; Brussels.—30th. Westmoreland.
- Oct. 3, 6, Carlisle.—13th. Westmoreland.—14th. Bonn.—17th. Basle; Gastein.—23rd. Parma; Brussels.—24th. Cadiz, Spain; Parma; Paris, Bourges, &c.; Cambridge, Durham, York, Swansea, Blackheath, Mont-eagle, Oxford, Ipswich, Greenwich, London, Ireland, &c.; Brussels; Mannheim; Wurtemberg; Leipzig.—25th. Rouen.—27th. Brighton, Cambridge, Oxford, and other parts of England.—28th. Cambridge.
- Nov. 1. Paris.—2nd. Bonn.—17th. Montpellier, Paris.—18th. Brussels.—19th. Bonn, Leipzig.—20th. (?).—22nd. Leipzig.—25th. Rouen.
- Dec. 8, 10, Bonn.—16th. Baden, Wurtemberg.—17th. Madrid; Pisa, Florence; Toulouse, Montpellier, Bordeaux, Grenoble, Bourg, Cirey, Saint-Symphorien-en-Laye, Bourges, la Ferté-sous-Jouarre, Gersdorff, département de la Seine, Blangy, Havre, almost all France; Brussels, Amsterdam; Basle, Neuchâtel; Bonn, Kirchheim; Karlsruhe; Freudenstaedt, Halle, Calw, Stuttgart, Heilbronn, &c.; Botzen, Balingen, Dresden, Leipzig; Eutin, Koenigsberg.—18th. Eutin.—19th. Nuremberg; Dresden; Eutin.—20th. Bonn; Eutin.—31st. Leipzig.
1848. Jan. 11. Mannheim.—16th. Greenwich.—20th. Leip-

- zig.—25th. Gœrsdorff (Upper Rhine).—
28th. Bonn; Leipzig.
1848. Feb. 20. Greenwich, and great part of England.—21st.
Milan; Bourg, Gœrsdorff; England; Zurich,
Baale; Bonn; Wurtemberg; Seelau, Leit-
meritz, Purglitz, Pilsen, Hohenelbe, Dresden,
Warza, Leipzig, Pegau, Lutzen, Merseburg,
Zeitz, &c.—22nd. Parma; Greenwich, Dur-
ham; Kremsmunster, Klagenfurt; Leit-
meritz, Purglitz.—24th. Atlantic, $58^{\circ} 41'$
lat. N., and $18^{\circ} 45'$ long. W.—25th. Leit-
meritz.—27th. Montpellier.
- Mar. 7. Bonn.—15th. Stonyhurst.—19th. Green-
wich, Durham, England; Bonn.—20th.
Greenwich, Durham, Stonyhurst.—21st.
England.—28th. Leeds.—31st. Greenwich,
Stonyhurst.
- April 2. Leipzig.—3rd. Greenwich, England.—5th.
Leipzig.—6th. Brussels, Aix-la-Chapelle.—
7th. Greenwich, England.—17th. Green-
wich, Stone.—29th. Greenwich, England;
Leipzig and district.
- May 11. Greenwich.
- July 8. Atlantic, $52^{\circ} 12'$ lat. N., and $8^{\circ} 32'$ long. W.—
11th. England, Atlantic, $46^{\circ} 16'$ lat. N. and
 $86^{\circ} 26'$ long. W.—24th. Parma.
- Aug. 19. Portsmouth.—28th. England.—30th. Parma.
- Sept. 4, 8, 18. England.—23rd. Atlantic, $51^{\circ} 16'$ lat.
N., and $12^{\circ} 20'$ long. W.—30th. Aix-la-
Chapelle.
- Oct. 17. Stonyhurst; Stubenbach; Kremsmunster.
—18th. Spain; Greenwich, Cambridge,
Stonyhurst, &c., and many parts of England;
Atlantic, $49^{\circ} 4'$ lat. N. and $19^{\circ} 10'$ long. W.;
Frankfort-sur-Mein; Salzburg, Strakowitz,
Winterberg, Kremsmunster.—19th. Green-
wich, Stonyhurst, various parts of England;
Atlantic, $50^{\circ} 16'$ lat. N., and $18^{\circ} 20'$ long. W.,
and $48^{\circ} 35'$ N. lat., and $14^{\circ} 2'$ W. long.; Aix-
la-Chapelle, Bonn; Cracow.—20th. Green-
wich, Stonyhurst, and other parts of Eng-
land.—22nd. Greenwich, England; Brussels.
Aix-la-Chapelle, Bonn; Stubenbach.—23rd;
Montpellier; Atlantic, lat. 49° N., and 14°
long. W.; Brussels; Haltimer (near Namur);
Aix-la-Chapelle, Bonn; Ittersdorf (Lake of

- Constance); Leipzig.—24th. Parma; Paris; Greenwich, England; Brussels; Aix-la-Chapelle, Bonn.—25th. Greenwich, England; Brussels; Aix-la-Chapelle; Bonn.—26th. Brussels; Aix-la-Chapelle; Bonn.—27th. Greenwich, Prestwich, England.—28th. Bonn.—29th. Bonn; Leipzig.—30th. Greenwich, England.—31st. Kremsmunster.
1848. Nov. 5, 6. Parma.—13th. Greenwich.—14th. Greenwich, England.—17th. Smyrna, Salonica; Odessa; Madrid, Spain; Rome, Florence, Pisa, Parma, Venice, Milan; Montpellier, Grenoble, Saint-Laurent-du-Pont, Bordeaux, Toulouse, Rodez, Bourg, Cirey, Paris, Havre, Dieppe, &c.; Greenwich, Stonyhurst, Cambridge, Liverpool, Manchester, Durham, &c.; Bruges, and other places in Belgium; Zurich, Basle; Aix-la-Chapelle; Kassel; Stuttgart and other places in Wurtemberg; Kremsmunster, Freistadt, Leitmeritz, Schössel, Strakowitz, Seelan; Hohenelbe, Prague; Stubenbach; Dresden, Leipzig; Berlin.—18th. Greenwich, Prestwich, and other parts of England; Brussels; Aix-la-Chapelle.—19th. Atlantic, lat. $50^{\circ} 11' N.$, and $15^{\circ} 30' W.$; Geneva; Bonn.—21st. Parma; France; Greenwich, Prestwich, and many parts of England; Brussels; Aix-la-Chapelle, Bonn; Leitmeritz; Cracow.—22nd. Leitmeritz.—23rd. Greenwich, England.—24th. Parma; Greenwich, England.—25th, 26th. Greenwich, England.—28th. Stubenbach.—30th. Greenwich, England.
- Dec. 10. Greenwich. — 13th. Greenwich, England; Brussels; Aix-la-Chapelle.—17th. Parma; Prestwich; Basle; Kremsmunster; Göttingen; Leipzig.—21st. Atlantic, lat. $54^{\circ} 8' N.$, and $26^{\circ} 10' W.$ —22nd, 27th, 29th. Greenwich, England.
1849. Jan. 1, 8. (?)—4th. Prestwich.—9th, 12th, 13th. (?)—14th. Paris; Prestwich, Whitehaven, Aylesbury, Maidenstone Hall.—15th. Hartwell.—22nd. Parma.—27th. Smecna (Austria.)
- Feb. 18. Whitehaven, Wakefield.—19th. Prestwich, Stone, Whitehaven, Wakefield; Atlantic,

- lat. $50^{\circ} 43' N.$ and $33^{\circ} 20' W.$; Basle; Leipzig.
 — 20th. Greenwich, Whitehaven, Hartwell; Atlantic, lat. $50^{\circ} 16' N.$ and $14^{\circ} 20' W.$; Leipzig.—21st. Hartwell; Leipzig.—22nd. Parma; Montpellier; Greenwich, Oxford, Holkham, Anglesbury, Stone, Norwich, Newcastle; Brussels, Waremm, Liege; Bonn; Basle; Ulm.—23rd. Whitehaven, Hartwell; Bonn.—24th, 25th. Bonn.—26th. Aix-la-Chapelle.—27th. Montpellier; Greenwich; Brussels; Aix-la-Chapelle, Bonn, Pegau; Mergentheim, and other parts of Wurtemberg; Pilsen.
1849. Mar. 16, 17. Aix-la-Chapelle.—18th. Stone.
 — May 13. Atlantic, $51^{\circ} 15' N.$ and $15^{\circ} 20' W.$ —81st. Stone.
 — June 15. Stone.—26th, 30th. Latimer.
 — Aug. 11. Parma.—18th. Whitehaven.—29th. (?).
 — Sept. 8. Latimer.—16th. Stonyhurst.—27th. Bonn; Breslau.
 — Oct. 1. Whitehaven.—15th. Cambridge, Stonyhurst. 21st. Aix-la-Chapelle.—22nd. Greenwich, Carlington; Aix-la-Chapelle, Bonn; Mergentheim; Winterberg, Juterbogk; Leipzig.—23rd. Bonn.—24th. Bruxelles, Bonn.
 — Nov. 5. Bonn; Senftenberg.—9th. Bruxelles. 19th. Bonn.—24th. Senftenberg.
 — Dec. 14. Berne.
1850. Jan. 5. Greenwich.—19th. Atlantic, lat. $50^{\circ} N.$ and $26^{\circ} 20' W.$ —30th. Hartwell.—31st. Atlantic, on the route between Liverpool and New York.
 — Feb. 8. Atlantic, lat. $53^{\circ} 30' N.$ and $35^{\circ} 20' W.$ —6th. Whitehaven, Stonyhurst, Durham.—9th. Manchester.—10th. Stone.—11th. Aix-la-Chapelle.—12th. Durham.—18th. Aix-la-Chapelle.—23rd. Parma; Senftenberg.
 — Mar. 9. Whitehaven.—10th. Nottingham, Stonyhurst.—11th. Greenwich, Stonyhurst.—27th. Rose Hill near Oxford.—28th. Stone.—29th. Stone, Leeds.
 — April 5. Whitehaven.—6th. Durham.—26th. Senftenberg.
 — May 12. Oxford, Aylesbury, Stonyhurst, Durham; Senftenberg.
 — June 4. Reigern near Brünn.—5th. Nottingham, Highfield House.—13th. Oxford, Hartwell

- House, Rose Hill near Oxford; Bonn.—
26th. Manchester.—27th. Nottingham,
Chesterfield.
1850. July 5. Norwich.—12th. Norwich, Nottingham.—
27th. Atlantic, lat. 51° N. and 19° W.—
28th. Atlantic, lat. 52° N. and 16° W.
- Aug. 6, 21. Stone.
- Sept. 6, 10. Nottingham.—13th. Nottingham, Haw-
arden; Hamburg.—14th. Stone.—18th.
Parma, Hartwell, Stone.
- Oct. 1. Greenwich, Cambridge, Saint-Ives, Hunts,
Stone, Grantham, Liverpool, Manchester,
Durham, Whitehaven, &c.; Hamburg.—
2nd. Ostend, Namur, Aix-la-Chapelle,
Bonn; Hamburg.—3rd. Hamburg.—5th.
Rose Hill near Oxford.—8th, 9th. Holk-
ham.—10th. Rose Hill.—15th. Manches-
ter.—29th. Stonyhurst, North Shields.
- Nov. 2. Midhurst.—3rd, 4th. Rose Hill.—9th, 10th.
Jersey.—12th. Holkham.—14th, 15th, 16th.
Parma.—21st. Cambridge.
- Dec. 23, 26. Holkham.—27th. Hartwell, Midhurst,
Holkham, Whitehaven.
1851. Jan. 1, 5. Hawarden.—9th. Highfield House near Not-
tingham.—24th. Stonyhurst.
- Feb. 1. Rose Hill, Stonyhurst, Highfield House.—
2nd. Bonn.—5th. Durham, North Shields,
Atlantic, lat. 49° N. and 24° W.—6th. Rose
Hill.—7th. Stone.—8th. Atlantic, 51° N.
and 81° W.—10th. Atlantic, lat. 51° N.
and 30° W.—11th. Jersey.—18th. Grant-
ham, Stone; Basle.—19th. Hawarden,
Durham.—20th. Hawarden.—23rd. Dur-
ham.—24th. Hawarden.
- Mar. 7. Stone, Hartwell Rectory.—8th. Stone.—10th.
North Shields.—14th. Durham.—18th.
Hartwell.
- April 7. Leeds.—18th. Nottingham.—21st. Hawarden,
Grantham.
- May 15. Whitehaven.
- June 19, 20. Nottingham.
- Aug. 10. (?)—13th, 14th. Stone.—21st. Nottingham.
—24th. Hawarden, North Shields; Leip-
zig; Cracow.—29th. Atlantic, par 51° N.
and 18° W.—30th. Stonyhurst, White-
haven.

1851. Sept. 4. Kew.—6th. Durham, Whitehaven.—7th. Whitehaven.—14th. Hartwell Rectory, Whitehaven.—15th. Stone, Hartwell Rectory, Nottingham, Gainsborough, Stonyhurst, Harpham, Whitehaven, Durham, Yorkshire.—22nd, 24th, 26th. Aix-la-Chapelle (traces).—27th. Hawarden, Durham.—28th. Norwich, Harpham, Durham.—29th. Cardington, Hartwell Rectory, Hartwell House, Maidenstone Hill, Stone, Nottingham, Wakefield, Durham, North Shields; Purglitz; Calw, Stuttgart, Bœblingen, Vaihingen.—30th. Nottingham, Yorkshire; Prague; Camenz, Neunkirchen, Leipzig.
- Oct. 2. Maidenstone Hill, Oxford, Cardington, Norwich, Nottingham, Stonyhurst, Whitehaven, Durham, North Shields, Yorkshire; Bruxelles, Namur, Ostend; Aix-la-Chapelle, Bonn; Senftenberg, Dresden, Neunkirchen, Varsovie.—3rd. Cardington, Nottingham, Aix-la-Chapelle.—4th. Nottingham, Durham.—13th. Audierne (Finisterre).—14th, 15th. Stonyhurst.—18th. Durham, Bonn.—28th. Wakefield, Stonyhurst, Durham, Whitehaven, North Shields.—29th. Hartwell Rectory, Nottingham, Wakefield.
- Nov. 4. Aylesbury, Nottingham.—5th, 6th, 13th. Stonyhurst.—17th. Verden sur l'Aller.—20th. Aylesbury; Verden.—21st. Aylesbury.—26th. Stonyhurst.—30th. Verden.
- Dec. 6. Wakefield, Durham, Hawarden, Liverpool, North Shields.—8th. Hawarden.—13th. Aix-la-Chapelle.—18th, 21st. Verden.—22nd. Stonyhurst, Whitehaven, Nottingham, Hawarden, Durham, North Shields.—23rd. Whitehaven.—25th. Verden.—28th. Grantham; Gembloux, near Namur.—29th. North Shields, Grantham, Stonyhurst.—31st. Osnabruck.
1852. Jan. 2. Cracow.—3rd. Verden.—4th. North Shields.—17th. Durham.—19th. Bonn, Saarbruck, Birkenfeld, Elberfeld; Berne; Verden; Leipzig.—20th. Falmouth; Atlantic, lat. 49° N. and 11° W.—21st. Aylesbury, Durham.—22nd. Hartwell Rectory.—23rd. Oxford, Hatton, Hartwell Rectory, Carding-

- ton, Grantham, Gainsborough, Hawarden, Durham.—25th. Durham, Hawarden, Manchester, Stonyhurst; Verden.—80th. Rose Hill, Thame, North Shields.
1852. Feb. 4. Highfield House.—15th. Greenwich, all England between 51° and 55° N.—16th. Greenwich.—17th. Greenwich, Durham, Highfield House, North Shields.—18th. Greenwich, all England between 50° and 57° N.; Salzhausen; Breslau, Verden.—19th. All England between 49° and 57° N.; Bonn; Berne; Heilbronn, Calw; Husum; Eutin; Altona; Vienna; many parts of Germany; Preny (Poland.)—20th. Greenwich; Helston, Norwich; Atlantic, lat. 51° N. and 17° W.; Holitsch, Vienna; Cracow; Verden.—21st. Whitehaven, Durham, Gainsborough, Wakefield, Stonyhurst, Helston, Grantham, Highfield House, Glasgow.—22nd. Highfield House; Verden.—23rd. Stonyhurst, Durham.—25th, 26th. Highfield House.—27th. Durham, North Shields.—28th. Aylesbury.
- Mar. 2, 5. Highfield House.—12th, 15th. Verden.—17th. Coast of Essex between Blackwater and Crouch River.—20th. Stonyhurst.—21st. Hawarden, Saint-Ives.—25th. Stonyhurst.—26th. Bonn; Leipzig.—28th. Highfield House.—31st. Stonyhurst.
- April 1. Atlantic, lat. 51° N. and 9° W.—8th. Verden.—9th, 11th. Stonyhurst.—12th. Verden.—14th. Glasgow.—15th. Atlantic, lat. 47° N. and 31° W.—18th. Stonyhurst.—20th. Rose Hill.—21st. Oxford, Highfield House.—22nd, 23rd, 26th. Highfield House.
- May 1. Stone.—2nd. Stone, Hartwell Rectory.—3rd. Hartwell Rectory, Highfield.
- June 11. Greenwich.—19th. Stone.—24th. Highfield House.
- July 3, 6. England.—10th. Munster.—13th, 14th. England.
- Aug. 8. Atlantic, lat. 47° N. and 23° W.—10th. Bonn; Munster, Verden.—22nd. Laupen, near Berne.
- Sept. 4. Parma.—11th. England.—12th, 13th. Verden.—17th. England; Verden.—18th, 19th,

- 20th. England.—21st. England; Verden.
—29th. Paris.
1852. Oct. 5. Stone.—10th, 18th. Verden.—18th. Stuttgart; Verden.—23rd, 24th, 25th, 26th. Stone.
- Nov. 3. Stone, Oxford, Nottingham, Liverpool.—7th. Hawarden.—8th. Stonyhurst.—10th. Erlangen.—11th. Alsace; Lewisham, Greenwich; Basle, Lausanne, Coire, Grisons; Platinat; Karlsruhe, Mannheim, Stuttgart and all Wurtemberg; Salzburg, Vienna; Neunkirchen, Erlangen, Odenwald, Salzhäusen; Breslau.—12th. Linz; Cracow.—13th. Brunn.—17th. Senftenberg.—18th. Stone.—30th. Liverpool.
- Dec. 6. Erlangen; Vienna.—8th. Erlangen.—9th. Rose Hill.—12th. Stone.—14th. Erlangen.—15th. Grantham.—18th. Parma.—20th. Stone.
1853. Jan. 2. Paris.—4th, 5th. Hawarden.—7th. Clifton, Rose Hill, Stonyhurst; Erlangen.—8th. Stonyhurst.—12th. Erlangen.—15th. Clifton.—31st. Durham, Grantham.
- Feb. 44. Whitehaven.—15th. Nottingham.—16th, 17th. North Shields.—23rd. Nottingham.—27th. Nottingham, Hawarden, Stonyhurst, Whitehaven.—28th. Stone, Hartwell Rectory.
- Mar. 7. Midhurst, Clifton, Hawarden, Durham; Atlantic, lat. 51° N. and 21° W.—8th. Clifton, Stonyhurst, Durham.—17th. Stone, Bicester, Hartwell Rectory.—21st. Holkham.—29th. Stone.
- April 5. Greenwich, Stone, Hartwell House; Atlantic, 50° N. and 30° W.; Munster.—6th. Hawarden, Darlen.—7th. Stone, Hartwell Rectory, Hawarden.—8th. Hawarden, Stonyhurst, Durham.—24th. Hawarden.
- May 4. Hawarden, North Shields.—14th. Manchester.—24th. Nottingham.
- June 22. Greenwich.
- July 2. Venice; Biel (Hesse-Nassau).—12th. Hawarden; Vienna.
- Aug. 20, 26, 30. Hawarden.
- Sept. 1. Greenwich.—2nd. Greenwich, Exeter, Clifton, Warrington, Liverpool, Manchester, York, Cambridge, Durham, Hawarden, Makree,

- Dublin; Prague; Hamburg, Angeln.—3rd.
Clifton.—28th, 30th. Durham.
1853. Oct 17. Durham.—25th. Nottingham, Durham.—
29th. Whitehaven.—30th. Paris (?).—31st.
Cherbourg; Ampthill (Bedfordshire) and
many parts of England; Munster; Königs-
berg.
- Nov. 1. Oxford; Munster.—2nd. Whitehaven.—7th.
Leipzig.—8th. Isle of Man, Durham,
North Shields.—9th. Nottingham.—10th.
Leipzig.—22nd. North Shields, Isle of
Man, Durham, Stone, Stonyhurst; Leipzig.
—30th. Weischlitz.
- Dec. 5. Helston, Nottingham.—6th. Durham, Truro,
Clifton, Lewisham, Greenwich, Stonyhurst,
Isle of Man, Whitehaven, North Shields.—
8th. Durham.—23rd. Greenwich.—24th.
Clifton; Senftenberg.—25th. Senftenberg.—
26th. Falmouth; Senftenberg.—27th. Fal-
mouth.—28th. Warrington.—29th. Jersey;
Clifton.—30th. Jersey.
1854. Jan. 2. Rome: Königsberg.—31st. Greenwich.
- Feb. 10. Parma.—26th. Greenwich.
- April 13. Greenwich; Xanten am Rhin; Munster; Ham-
burg.
- June 24. Parma.
- July 15. Senftenberg.
- Sept. 14. Clays, near Amiens.—26th. Paris.
- Oct. 15. (?).
1855. Mar. 17. Berne.
- May 20 (?).
- Oct. 16, 18. Greenwich.
- Dec. 3. Atlantic, lat. 49° N. and 44° W.
1856. Feb. 1. Glarus (?), perhaps the zodiacal light.—3rd.
Munster.
- Mar. 12. Senftenberg.
- June 2, 3, 4. Paris.
- Dec. 8. Hanau.
1857. Nov. 22. Klosters (Switzerland).
- Dec. 17. Brussels; Bretten, Bruchsal, and all the West
of Wurtemberg.
1858. Mar. 9. Bonn; Putbus, Altona.—11th. Bonn.—13th.
Oxford.—14th. Oxford, Armagh.
- April 1. Rose Hill.—9th. Munster; Göttingen; Nau-
gard; Senftenberg, Dresden; Breslau.—10th.
Oxford, and many parts of England.—11th.

- Clifton.—12th. Silloth; Munster.—21st. Paris.—24th. Fairlight.—29th. Clifton.
1858. May 2, 6. Clifton.—7th. Oxford, Clifton.—8th, 10th. Clifton.
- June 6. Oxford.
- Dec. 4. South of France; Wurtemberg, Munster, Halle, and other parts of Germany; Prague, Jungbunzlau; Kremsmunster, Gaedonck, near Goch,—31st. Havre.
1859. Jan. 22. Helston.—23rd. Rose Hill.—29th, 30th, 31st. Athens.
- Feb. 2. Athens.—9th. Many parts of England.—11th, 12th, 14th. (?).—18th, 19th. Naugard.—22nd. Oxford, and many parts of England.—23rd. Oxford, and many parts of England; Prague; Munster; Naugard, Saalz, Hamburg, Rendsburg.—24th. Oxford and many parts of England; Naugard.—25th. Nottingham, Stonyhurst.—26th. Clifton; Munich.
- Mar. 2. Rose Hill.—25th. Saint-Paul's Parsonage.—26th. Oxford and many parts of England.—27th. Nottingham, Hawarden.—29th. Hawarden.—30th. Many parts of England.—31st. Saint-Paul's Parsonage.
- April 1. Eng'and.—7th. Paris.—14th. Armagh.—21st. Montpellier, Paris; Greenwich; Brussels; Vienna, Kremsmunster; Cracow, Prague; Munich, Bamberg; Halle, Dessau, Hœfgen near Grimma; Dresden, Oberwiesenthal, Leipzig; Berlin; Breslau.—22nd. Brussels; Munster, Gaesdonk.—23rd. Kremsmunster; Munster.—28th. England.—29th. Laer (Westphalie); Kremsmunster.
- May 1, 5. England.—31st. Athens.
- July 15. Wewelinghofen (Rhenish Prussia).
- Aug. 2. (?).—28th. Athens; Rome, Parma; Montpellier, Lyons, Paris, Saint-Valery; Noyelles-sur-Mer; London, Brighton, Clifton, and all England; Atlantic, lat. 26° N. and 29° W., and lat. 51° N. and 18° W.; Brussels; all Holland; Geneva, Basle, Rafz, Neuchâtel; Ittendorf (lake of Constance); Schemnitz (Hungary); Vienna, Olmutz, Prague; Bodenbach, Schossle, Bamberg, Neunkirchen, Stuttgart; Leipzig, Saxony, &c., and in general all Germany.—29th.

- Dunkirk; Prague.—30th, 31st. Grant-
ham; Vischel near Altenahr.
1859. Sept. 1. Grantham; Prague; Cracow.—2nd. Athens;
Rome; Clifton, Durham; Kremsmunster;
Cracow.—8rd. Athens; Clifton, Durham;
Kremsmunster; Cracow; Hamburg and
all Northern Germany; Königsberg, Cranz,
near Königsberg.—4th. Tottenham, Clifton,
Durham, Grantham, Newmark.—5th. Nau-
gard.—6th. Munster; Hamburg, Naugard.
—24th. Venice; Greenwich, South of Eng-
land; Holland; Kremsmunster; Prague;
Wurtemberg; Cologne, Crefeld, Hulsen near
Crefeld, Munster, Hamm, Elberfeld; Soest,
Lippstadt, Heiligenstadt.—25th. Munster.
—27th. Hamburg.
- Oct. 1. Toulouse, Lyon, Yzeure (Allier), Bois des
Fossés, Paris; Greenwich, Limerick, South
coast of England; Basle; Prague; Kreuz-
nach; Kremsmunster; Sankt-Wendel,
Munich; Naugard, Munster, Gaesdonck,
Hamburg; Anspach.—2nd. Madrid; Cas-
tera near Toulouse; Prague; Kassel.—10th.
Amiens.—12th. Athens; Naples, Rome;
Montpellier, Lyons, Yzeure, la Chaux-de-
Fonds, Saint-Arné (Vosges), Rouen, Amiens;
Southampton, Greenwich, Oxford; Luxem-
burg, Brussels, Namur; Berne, Neuchâtel;
Frankfort-on-the-Main, Kremsmunster;
Cracow; Wurtemberg; Kassel; Dresden,
Leipzig; Putbus; Berlin, Lichtenberg, near
Berlin, Hervest, near Dorsten, Naugard,
Stettin.—13th, 14th. Naugard.—15th. La
Turbie, near Monaco.—17th. Paris; Green-
wich, Oxford.—18th. Athens; Vienna.—
19th. Paris; Greenwich.—23rd. Reutlingen.
—24th. Atlantic, lat. 47° N. and 15° W.;
Peckeloh.
- Dec. 6. Rome.—13th. Oxford; Naugard.—21st.
Gresten (Austria).
1860. Jan. 1. Louvain.
- Feb. 12. Nottingham; Peckeloh.—23rd. Leipzig.
- Mar. 12, 18, 22, 25. Nottingham.—26th. Dresden.
- April 9. Paris; Greenwich, Nottingham; Brussels;
Wurtemberg, Munster, all Westphalia, Kre-
feld, Hamm, Wiedenbruck, Hamburg.—

- 10th. Paris.—12th. Paris; Hamburg.—
13th. Hamburg.—16th. Nottingham;
Munster.
1860. May 9. Oxford.
— Aug. 7. Clermont-Ferrand; Vienna; Prague; Berlin.
—8th. Athens; Clermont-Ferrand; Munich;
Naugard.—9th. Athens; Paris; Brussels;
Kremsmunster; Prague; Dresden, Brauns-
berg; Emden, Naugard, Lichtenberg near
Berlin, Lauenburg (Pomerania).—10th.
Athens; Nantes, Paris; Brussels; Nor-
derney; Dresden.—11th. Athens; Paris;
Prague; Peckeloh.—12th. Athens; Paris;
Yverdon; Kremsmunster, Vienna.—18th.
Athens; Emden, Westphalia.—14th. Athens.
—25th. Athens; Oelde (Westphalia).—27th.
Westphalia.—30th. Gouda (Holland).
- Sept. 6. Utrecht; Leipzig; Peckeloh.—7th. Paris;
Utrecht.—8th. Peckeloh.
- Oct. 1. Kreuznach.—19th. Putbus.
- Nov. 2. Nottingham.
- Dec. 8. Munster; Peckeloh.
1861. Jan. 24. Le Lochle; Munster, Peckeloh, Coesfeld,
Elberfeld, Gaesdonck.
- Feb. 12. Prague.—27th. Greenwich; Prague.
- Mar. 1. Oxford.—2nd. Groningen; Peckeloh.—4th.
Athens.—8th. Munster.—9th. Montpellier,
Paris; Greenwich, Oxford; Brussels,
Louvain, Nimeguen, Flushing, Delle, Ooster-
huizen, Workum, Utrecht, Slijk-Ewijk;
Geneva, Neuchâtel, Avenches, Saint-Aubin,
Lucerne; Kremsmunster; Prague, Gitschin,
Koeniggroetz; Saarbruck, Elsfléth, Gaes-
donck, Munster, Mannheim; Wurtemberg;
Peckeloh, Rhine, Berlin, Neumarck, Loebau,
Lübeck, Putbus, Dessau; Cracow.—19th.
Gitschin.—25th. Prague.
- April 7. Oxford; Slijk-Ewijk.—15th. Slijk-Ewijk,
Workum; Munster, Peckeloh; Berlin.—
24th. Munster.—25th, 28th, 29th. Prague.
- Aug. 12. Yverdon.
- Sept. 11. Munster.—25th. Workum.
- Oct. 2. Utrecht.—10th. Brussels, Utrecht; Peckeloh.
—12th. Greenwich.
- Nov. 8. Lichtenberg, near Berlin.—5th. Peckeloh.—

- 7th. Oxford; Ouddorp; Peckeloh, Lichtenberg, Ebstorf, Naugard.—24th. Oxford.
1861. Dec. 2. Prague; Dessau.—3rd. Peckeloh.—4th. Greenwich; Delle, Workum, Helder, Noord-Hinder near Gaesdonck, Peckeloh, Naugard; Carrow near Mecklenberg.—19th. Dresden.—20th. Basle.—23rd, 24th. Dresden.—26th. Dresden, Peckeloh.
1862. Jan. 17. Lichtenberg.—18th. Peckeloh; Lichtenberg.—22nd, 23rd, 26th. Lichtenberg.
- Feb. 8. Lichtenberg, Peckeloh.—18th. Peckeloh.—21st. Workum, Ouddorp, Helder, Noord-Hinder; Munster, Gaesdonk, Peckeloh.—22nd. Athens.—27th. Peckeloh.
- Mar. 1. Lichtenberg, Peckeloh.—3rd. Peckeloh.—4th. Munster; Peckeloh.—5th, 8th, 13th. Peckeloh.—14th. Athens.—24th, 25th, 27th, 28th, 29th. Lichtenberg.
- April 2, 3. Peckeloh.—13th. Paris.
- May 1. Milan; Peckeloh.—2nd. Peckeloh.—3rd. Milan.—18th. Wilna.—19th. Milan; Munster; Wilna.—20th. Milan; Wilna.
- June 4. Noord-Hinder.—5th. Brouwershaven.
- July 19. Senftenberg (Bohemia).—26th. Peckeloh.—27th. Milan; Peckeloh, Leipzig.—28th. Peckeloh.—29th. Leipzig.
- Aug. 4. Milan; Paris; Ootmarsum; Munich; Munster, Peckeloh.—19th. Noord-Hinder; Peckeloh.—20th. Peckeloh.—21st. Milan.—24th, 25th, 27th. Peckeloh.—28th. Milan; Senftenberg; Peckeloh; Naugard.—29th. Peckeloh.
- Sept. 2, 11, 13, 15, 16, 18. Peckeloh.—24th. Senftenberg, Naugard, Peckeloh.—29th, 30th. Peckeloh.
- Oct. 6. Peckeloh.—9th. Utrecht; Peckeloh.—11th. Montpellier.—15th, 17th. Peckeloh.—24th. Worthington (?).—28th, 31st. Peckeloh.
- Nov. 19, 29. Peckeloh.
- Dec. 4. Peckeloh.—14th. Rome, Bologna, Bergamo, Parenzo, Trieste; Marseilles, Montpellier, Puycharnaud (Dordogne), Limoges, Bellac, Paris; Greenwich, Queenstown; Brussels, Antwerp, Ghent, all Holland; Geneva, Neuchâtel, Basle, Zurich, Ittendorf; Co-blentz, Munster, Peckeloh; Wurtemberg;

- Leipzig, Salzhausen, Lichtenberg.—15th.
 Horst (Holland).—22nd. Lichtenberg.—
 25th. Emden, Mannheim, Breslau.
1863. Jan. 7, 9. Peckeloh.—12th. Lyon.—15th. Mannheim.
 —25th. Noord-Hinder.
- Feb. 9. Berlin.—10th. Mannheim.—14th, 17th.
 Peckeloh.—22nd. Utrecht, Noord-Hinder;
 Ludingen (Hanover).
- Mar. 3, 4, 18, 21. Peckeloh.
- April 1, 7, 9, 10, 19. Peckeloh.
- May 1. Peckeloh.—6th. Leeuwarden.—9th. Peckeloh;
 Cracow.
- June 22. Peckeloh.—23rd. Noord-Hinder.
- Aug. 9. Mannheim.—17th. Munster.
- Sept. 20. Peckeloh.
- Oct. 7, 8. Peckeloh.—11th. Munster.—25th. Peckeloh.
- Nov. 1, 2. Peckeloh.—9th. Utrecht; Munster; Peckeloh.
 —10th. Lichtenberg.—11th. Peckeloh;
 Lichtenberg.—13th. Athens.—18th, 20th.
 Peckeloh.—29th. Munster; Peckeloh.
- Dec. 4. Peckeloh.—10th, 11th. Athens.—14th.
 Munster; Dresden; Peckeloh; Berlin.—
 18th. Peckeloh.
1864. Jan. 6, 14, 16, 17. Peckeloh.
- Feb. 1. Zurich.—9th. Berlin.—14th, 17th. Peckeloh.
- Mar. 6. Peckeloh.—7th, 8th, 9th. Lichtenberg.—10th.
 Munster; Naugard; Peckeloh; Berlin,
 Lichtenberg.—14th. Hanover.—18th, 22nd,
 25th. Peckeloh.
- April 2. Lichtenberg.—5th. Munster; Peckeloh.—8th.
 Lichtenberg.—16th, 20th. Peckeloh.—27th.
 Munster; Naugard; Peckeloh.—30th.
 Peckeloh.
- May 3. Peckeloh.—9th. Cracow.—12th. Peckeloh.
- June 12, 18. Peckeloh.—18th. Lisbon.
- July 10. Zurich.—12th, 28th. Peckeloh.
- Aug. 1, 2. Kephissia near Athens.—5th. Peckeloh.—
 6th. Athens.—9th. Kephissia.—17th.
 Munster; Peckeloh.—31st. Naugard.
- Sept. 18, 14. Peckeloh.—25th. Peckeloh; Aardenburg.
 —27th, 29th. Peckeloh.
- Oct. 7. Westphalia.—8th. Munster, Westphalia;
 Naugard; Peckeloh.—11th. Munster.—
 15th. Lichtenberg.—19th. Valentia (Ire-
 land); Peckeloh; Lichtenberg.—21st. Paris.
 —25th. Peckeloh.

1864. Nov. 2, 7. Peckeloh.—9th. Munster; Peckeloh.—23rd. Peckeloh.—29th. Munster; Peckeloh.—30th. Juliers.
- Dec. 11. Peckeloh.—18th, 22nd. Lichtenberg.—23rd. Munster; Peckeloh.—24th. Frankenthal (Rhenish Bavaria); Munster.—29th, 30th, 31st. Lichtenberg.
1865. Jan. 6. Munster.—9th. Rome.—12th. Peckeloh.—17th. Marseilles; Munster; Peckeloh; Lichtenberg.—24th. Marseilles; Munster.—25th. Leeuwarden.—27th. Paris.—29th, 30th. Lichtenberg.
- Feb. 15. Peckeloh.—17th. Greenwich; Cork; Munster; Peckeloh; Lichtenberg.—18th. Naugard; Lichtenberg.—21st. Peckeloh.—22nd. Peckeloh; Lichtenberg.—23rd, 27th. Lichtenberg.
- Mar. 4. Peckeloh.—7th. Gorcy near Metz.—18th. Bamberg; Peckeloh.—19th. Lichtenberg.—20th. Greenwich; Munster; Peckeloh; Naugard; Lichtenberg.—21st, 22nd. Bamberg; Lichtenberg.—23rd. Lichtenberg.
- April 8, 9, 16. Peckeloh.—28th. Berne.
- June 17. Athens.—28th. Peckeloh.
- July 18. Munster.—19th. Peckeloh.
- Aug. 2. Munster; Peckeloh; Sudenburg near Magdeburg.—18th, 14th. Peckeloh.—18th. Leeuwarden.—19th. Munster; Papenburg.—25th. Peckeloh.—26th. Ostend; Munster; Peckeloh; Papenburg.
- Sept. 16, 21, 22. Peckeloh.—26th. Papenburg.
- Oct. 13, 14, 28, 31. Peckeloh.
- Nov. 7. Helder.—8th. Vendôme; Valentia.—9th. Papenburg.—14th. Munster; Peckeloh; Papenburg.
1866. Jan. 4. Peckeloh.—6th, 12th. Lichtenberg.—29th. Peckeloh.
- Feb. 6. Peckeloh; Lichtenberg.—7th. North Shields, Bywell; Papenburg; Lichtenberg.—9th. Peckeloh.—12th. Greenwich; North Shields.—13th. N. Shields.—15th. Lichtenberg.
- Mar. 7. Peckeloh; Papenburg; Lichtenberg.—8th. Lichtenberg.—14th. Peckeloh; Lichtenberg.—15th. Lichtenberg.—16th. Peckeloh.—17th. Paris.—20th. Peckeloh.
- April 8. Lichtenberg.—9th, 23rd, 26th. Peckeloh.

1866. May 14, 19. Peckeloh.
 — June 13. Peckeloh.
 — July 15. Peckeloh.
 — Aug. 11. Peckeloh.—14th. Atlantic, lat. 54° N. and long 24° W.
 — Sept. 2, 4, 8. Peckeloh.
 — Oct. 1, 2. Peckeloh; Lichtenberg.—3rd. Munster; Peckeloh; Lichtenberg.—4th. Peckeloh; Lichtenberg.—5th. Munster; Lichtenberg.—6th. Lichtenberg.—8th, 10th. Peckeloh.—11th. Lichtenberg.—14th, 22nd, 23rd, 25th. Peckeloh.
 — Nov. 1. Munster; Peckeloh.—4. Lichtenberg.—10th. Brussels; Munster.—11th. North Shields, Allenheads.—12th. Lichtenberg.—19th. Allenheads.—24th, 25th. Peckeloh.—26th. Peckeloh; Hamburg; Papenburg; Lichtenberg.—27th. Lichtenberg.—28th. Munster.—29th. Bywell; Lichtenberg.—30th. Lichtenberg.
 — Dec. 8, 10. Lichtenberg.—25th. Allenheads, Bywell.—30th. Lichtenberg.
 1867. Jan. 28. Marseilles; Platta (Switzerland).
 — Mar. 21. Peckeloh.
 — May 3. Peckeloh.—4th. Pussen.—17th. Tarifa.—19th. Peckeloh.—23rd. Neuchâtel. (Switzerland) (doubtful).—25th. Peckeloh.
 — June 12. Cracow.
 — July 3. Peckeloh.
 — Aug. 26. Peckeloh.
 — Sept. 12. Peckeloh.—25th. Lichtenberg.—26th. Peckeloh; Lichtenberg.
 — Oct. 21, 22, 26. Lichtenberg.—27th. Peckeloh.—28th. Peckeloh; Lichtenberg.—30th. Lichtenberg.
 — Nov. 2. Peckeloh.—27th, 28th. Lichtenberg.
 — Dec. 2. Lichtenberg.
 1868. April 2. Peckeloh.—20th. Ireland.
 — May 20. Greenwich.
 — Oct. 22. Munster; Peckeloh.
 — Nov. 14. Peckeloh.—19th. Munster; Peckeloh.
 — Dec. 4, 12, 14. Lichtenberg.
 1869. Jan. 7. Peckeloh.—11th, 12th. Lichtenberg.
 — Feb. 3. Greenwich; Naugard; Koeslin; Danzig; Putbus.—5th. Breslau.—14th. Padua, Moncalieri.

1869. Mar. 6, 7, 12, 13, 31. Peckeloh.
 — April 1, 2. Peckeloh.—15th. Paris and the greater part of France from south to north; London, Greenwich, Liverpool; Brussels, Utrecht, the whole of Holland; Zurich, Altorf, Gersau, Einsiedeln, Altstätten, Saint-Gall, Brienz; Sankt-Gyorgyi (Hungary); Chlumetz; Munich; Munster; Peckeloh, and many parts of Germany.—16th. Greenwich; Danzig.—17th. Lichtenberg.
 — May 5. Peckeloh.—8th. Rome.—9th. Danzig.—13th. Azores; Athens; Rome, Leghorn, Venice, Padua; Trieste, Pola, Lesina, Zombor; Paris and the north of France; Greenwich, Llanrwst, Shrewsbury, Manchester; Brussels; Amsterdam, Workum, and the whole of Holland; Splugen, San-Vittore, Sils Maria, Gröchen, Vaudens, Einsiedeln, Schwyz, Berne and all the north of Switzerland, Buda, Altenburg (Hungary); Vienna, Baden near Vienna, Ischl, Görz, Laibach, Gratwein; Cologne, Munster; Hamburg; Munich; Peckeloh, Berlin, Lichtenberg, &c.—14th, 15th. Paris.—29th. Hungary.
 — June 7. Peckeloh.—29th. Greenwich.
 — July 29. Zurich.
 — Aug. 5. Zurich.—10th. Athens.
 — Sept. 3. Greenwich; Lichtenberg.—4th. Munster; Peckeloh.—5th. Paris; Danzig.—11th. Peckeloh; Lichtenberg.—22nd. Danzig.—25th. Lichtenberg.—27th, 28th, 29th. Peckeloh.
 — Oct. 1, 3, 5. Munster.—6th. Paris; London, Greenwich; Brussels, Louvain; Aix-la-Chapelle; Munster; Flensburg, Keitum, Wolgast. Schleswig.—18th. Danzig.—21st. Athens.—25th. Peckeloh; Posen.
 — Nov. 3. Lichtenberg.—10th. Altenburg.
 — Dec. 7. Munster; Peckeloh.—11th. Hermannstadt.—25th. Grullenberg (Saxony); Peckeloh.—30th. Peckeloh.
 1870. Jan. 1. Culloden; Gratz, Meseritz, Reitzenhain.—2nd. Culloden.—3rd. Volpeglino, Piedmont; Nantes, and other parts of France; Guernsey; Worthing, Royston, Somerleyton, Norwich, Boston, Eccles, Culloden; Brus-

- sels.—4th. Wisbech.—6th. Munster; Papenburg.—8th. Oxford, Liverpool, Cockermouth, North Shields.—10th. Eastbourne.—20th. Munster, Peckeloh.—23rd, 26th. Culloden.—28th. Liverpool, Carlisle, Culloden.—29th. Liverpool, Carlisle, Culloden, Allenheads.—30th. Weybridge, Hawsker; Brussels; Munster; Lennep; Peckeloh.—31st. Lennep; Peckeloh.
1870. Feb. 1. Paris, Calais; London, Diss, Eastbourne, Wisbech, Boston, Royston, Little Wrating, Norwich, Somerleyton, North Shields, Culloden; Brussels, Kain near Tournay, Ruhrort, Munster; Munich; Lennep; Peckeloh; Dresden, Græditz; Grullenberg; Lichtenberg; Kœslin, Königsberg; Cracow.—2nd. Culloden, Weybridge.—3rd, 4th. Culloden.—11th. York, Hawsker, North Shields, Taunton, Wilton, Streatly, Little Wrating, Cardington.—12th. Helston, Cockermouth.—17th. Leipzig.—19th. Truro.—21st. Hawarden.—23rd. Culloden.—27th. Peckeloh.—28th. Weybridge, Hawarden, Culloden.
- Mar. 1. Hawarden.—3rd. Cardington, Boston.—13th. Oxford, Taunton, Boston, Hawsker.—14th. Guernsey.—22nd. Stonyhurst, York, Little Wrating.—24th. York.—25th. Weybridge.—28th. Lichtenberg.—30th. Oxford, Valentia; Westphalia.
- April 5. Athens; Fiume; Piacenza, Volpeglino, North de Italy; Macon, Angiers, le Mans, Nantes, Brest, Paris, all the north of France; London; Brussels, Louvain, Kain, Grammont; Flushing, Utrecht, Leeuwarden; Splugen, Græchen, Vuadens, all north-eastern Switzerland; Mayence, Sinzig, Bonn, Westphalia; all North Germany; Buda, Isohl, Feldkirk; Munich, Deutsch Krone; all Saxony; Karnik near Posen.—18th. Greenwich; Peckeloh, Lennep; Stettin.—23rd. Papenburg.—25th. Reitzenhain.
- May 19. Greenwich.—20th. Paris; London; Mannheim; Munster; Zurich; Hermannstadt, Oravitz, Fiume, Tisza Fured, Debreczin, Edelény, Rechnitz, Gospic.

1870. June 1. Louvain.
- Aug. 1. Peckeloh.—3rd. Amsterdam.—19th. Munster;
Carthaus near Dulmen.—20th. Groningen;
Munster, Peckeloh; Leipzig.—21st. Vol-
pegliano.
- Sept. 2. Athens.—3rd. Greenwich; Hamburg; Debeln;
Niederorschel.—4th. Workum, Zuidbroek;
Niederorschel; Norburg off Alsen; Schleswig.
—18th. Hamburg.—21st. Hamburg, Nor-
burg, Schleswig; Lichtenberg.—22nd, 23rd.
Peckeloh.—24th. Moncalieri and all Pied-
mont; Vendôme; London, Hawkhurst;
Brussels, Louvain, Stavelot; Groningen;
Mayence; Zurich; Vienna, Kremsmunster;
Prague, Eger; Buda, Edeleny, Obernberg sur
Inn, Enzersdorf im Thale; Niederorschel,
Carthaus near Dulmen, Weisenheim am Bry;
Munster; Peckeloh, Wollgast; Alsen, Nor-
burg off Alsen, Schleswig; Berlin, Danzig.—
25th. Greenwich; Ostend, Kain; Ouddorf,
Welna, Boekhorst, Terborgh and all Zealand;
Zurich; Munster; Hamburg; Weisenheim
am Bry, Carthaus near Dulmen; Peckeloh,
Schleswig; Rehfeld; Danzig.—26th. Green-
wich; Ouddorp, Welna, Boekhorst, Terborgh
and all Zealand, Hamburg, Keitum; Weisen-
heim am Bry; Peckeloh; Lichtenberg.—
27th. Hamburg; Schleswig; Peckeloh.—
20th. Lichtenberg.
- Oct. 1. England; Westphalia.—2nd, 3rd. England.—
14th. Vendôme; Greenwich, England;
Holland; Schönenberg (canton of Zurich);
Edeleny; Grœditz Bautzen; Munster;
Putbus, Hamburg; Lichtenberg; Cracow.—
15th. Holland.—17th, 18th. England.—
20th. Vendôme; England; Aarau, Brugg,
Muri; Westphalia; Riesa.—21st. England;
Norburg off Alsen.—22nd. England;
Cologne; Hinterhermsdorf; Cracow.—23rd.
Fiume.—24th. Bagdad; Athens; Constan-
tinople, Lala Tehiflik, to the south of Andri-
nople; Roustchouck, Orsova; Lisbon, Oporto,
Madrid; Palermo, Catania, Otranto, Rome,
Florence, Fiesole, Perugia, Leghorn, Milan;
Trieste, Lissa, Lesina, Fiume; Saint-Peter
near Gœrz, Modena, Varallo, Moncalieri.

- Alexandria; Paris, Tours, Metz, the whole of France; London, Greenwich, Torquay, Scarborough, Penzance, Valentia, the whole of England; Brussels, Louvain, Kain, Ostend, &c.; all Holland; Bellinzona, Lugano, Monte Generoso, Brusio, Splügen, Coire, Einsiedeln, Berne, Altorf, Geneva, all northern Switzerland; Vienna, Kremsmunster; Hermannstadt, Sächsisch-Regen; Karlsburg; Leipzig, Saxony; Munster, Hamburg; Niederorschel, Carthaus, Peckeloh; Berlin, Stettin, Breslau, Danzig and North Germany.—25th. Corfu; Athens, Greece; Constantinople, Turkey in Europe, Orsova, Rustchuck, Serajevo, Prevesa; Lisbon, Oporto, Madrid; Cataro, Castelnova, Lesina, Lissa, Fiume, Trieste, Palermo, Catania, Otranto, Naples, Rome, Fiesole, Florence, Modena, Milan, Genoa, Turin, Moncalieri; Paris, Tours, Metz and all France; London, Scarborough; Brussels, Louvain, Kain, Ostend; Vienna, Kremsmunster, Oberhollabrunn, Presburg, Buda, Gyalla; Munster, Niederorschel, Keitum, Hamburg; Leipzig, Saxony; Schleswig, Peckeloh, Berlin, Breslau and all Germany.—26th. Athens.—27th. Athens; Monte Generoso; England; Hamburg.—28th. Athens; England; Hamburg.—29th. Hamburg; Lichtenberg.—30th. England.
1870. Nov. 1. England; Hamburg.—8th. Leeuwarden; Schleswig; Leipzig, Saxony.—14th, 17th, 18th. England; Saxony.—19th. England; Brussels, Louvain, Verviers; Zurich, Coire; Munster; Schleswig; Eger; Leipzig, many parts of Saxony; Niederorschel; Peckeloh.—21st. England.—22nd. Mediasch (Transylvania); England.—25th. England.—27th. Brunn.
- Dec. 15. England.—16th. England, Westphalia; Keitum; Schleswig; Peckeloh.—17th. Vendôme; England; Brussels. Louvain, Græchen; Munster; Keitum; Schleswig; Zittau; Peckeloh, Putbus; Breslau.—22nd. Schleswig.—26th. Peckeloh.
1871. Jan. 12. Louvain.—13th. London; Louvain; Cologne,

- Munster; Peckeloh, Schleswig; Tharandt; Breslau.—14th. Louvain.—15th. Schleswig; Breslau.—16th. Louvain.
1871. Feb. 5. Breslau.—9th. Cleves; Putbus.—11th. England; Cleves, Emden, Westphalia, Keitum; Peckeloh; Wollgast; Putbus.—12th. Rome, Frascati, Florence, Modena, Volpeglino, Moncalieri; Greenwich, West Coasts of England, Louvain; Mayence, Cleves; Altorf, Coire, Ragatz; Vienna, Eger; Daschitz (Moravia); Saxony; Munster; Niederorschel; Peckeloh; Weserleuchtthurm; Wollgast; Breslau, Putbus, Kœslin, Stettin.—13th. England.—14th. Volpeglino.—15th. Rome; Zurich.
- Mar. 12. London.—13th. Gullenberg (Saxony).—14th. Bautzen, Dresden, Wermsdorf; Grœditz, Zittau, Plauen, Kœnigstein.—16th. Roche's Point; Munster; Peckeloh.—17th. Piedmont.—18th. Zurich; Gœrisch; Gœrlitz, Oberwiesenthal.—21st. Munster.—22nd. Leeuwarden.—23rd. Venice, Leeuwarden, Emden; Cleves; Munster; Wollgast; Peckeloh.—29th. Emden.
- April 1. London; Brussels; Cleves; Treves; Breslau.—2nd. Stettin.—8th. Turin, Moncalieri; Breslau.—9th. Palermo, Perugia, Piacenza, Padua, Milan, Trente, Tortona, Volpeglino, Alexandria, Moncalieri, Turin, Genoa; Angiers; England; Brussels, Louvain; Zurich, Glarus, Sargans; Vienna, Prague; Mayence, Frankfort; Keitum, Weserleuchtthurm; Bautzen; Stettin, and many parts of Germany.—10th. Moncalieri, Alexandria, Padua, &c., London; Peckeloh.—11th. Aosta; Westphalia; Peckeloh.—13th. Palermo, England.—14th. Leipzig, Dresden, Wermsdorf, Grœditz, Zittau, Kœnigstein, Plauen, and other parts of Saxony, Peckeloh, Stettin.—15th. Palermo, Piacenza; Peckeloh; Stettin.—16th. London; Stettin.—17th. Volpeglino; Stettin.—18th. Palermo, Perugia, Urbino, Florence, Lodi, Alexandria, Moncalieri, Volpeglino, Bra, Piedmont, Lombardy; Zurich, Aarau, Coire, Saint-Gall, Winterthur; Cilli; Oberwiesenthal, Grœditz,

- Leipzig; Breslau; Putbus, Kœslin, Stettin, Wollgast, Flensburg.—19th. Lohn.—21st. Ulm.—22nd. Paris.—23rd. Palermo, Lodi, Turin, Moncalieri, Alexandria, Bra, Genoa, Volpeglino; Munster.
1871. May 8. London, England.—16th. England.—17th. England; Peckeloh.—18th. Berne.—19th, 20th, 22nd, 26th. England.
- June 7, 12. Athens; Moncalieri.—18th. Cleves.—14th. Cleves; Peckeloh.—16th. Turin.—18th. Athens; Moncalieri.—27th, Moncalieri; Oxford.
- July 14. Moncalieri.—25th. Roche's Point.
- Aug. 10. Peckeloh.—11th. Valentia.—16th. England.—21st. London, Ireland.—23rd. Zurich; Emden.—24th. Aberdeen, Roche's Point; Brussels.
- Sept. 4. Ireland.—7th. Houlgate (Calvados); Wollgast.—16th. Roche's Point.—19th. Emden.
- Oct. 6. Emden.—10th. Zurich, Aarau; Mayence.—11th. Wollgast.—13th. London; Peckeloh.—15th. Peckeloh.—16th. London.
- Nov. 2. Volpeglino, Moncalieri, Aosta; Groninguen, Emden; Bonn; Gyalla (Hungary); Eger; Opladen, Husum, Kiel; Bergen on Rugen, Woolgast, Danzig.—3rd. Paris; Gyalla.—4th. Peckeloh.—5th. Gyalla.—7th. Peckeloh.—9th. Modena, Genoa, Turin, Moncalieri, Volpeglino; Angiers, Paris, Brest; Greenwich, England; Entremonts near Binche (Belgium); Emden; Bonn; Genoa; Woolgast, Opladen, Peckeloh; Kiel; Dingelstedt; Leipzig.—10th. Genoa, Lodi, Mondovi, Turin, Moncalieri, Volpeglino, Aosta; Paris; Greenwich, Scilly; Entremonts; Bonn; Eger; Woolgast, Opladen, Roessel, Dingelstedt; Danzig.—14th. Genoa; Alexandria.—15th. Genoa.—17th. Danzig.—18th. Emden.—20th. Aosta, Danzig.—24th. Volpeglino.
- Dec. 6. Peckeloh.—10th. Emden.—14th. Peckeloh.—18th. London.—31st. Roche's Point.
1872. Jan. 3. London.—5th. Modena.—6th. Palermo.—7th. Florence, Modena, Genoa, Aosta.—9th. Florence.—15th. Aosta.—18th. Emden.—21st. Florence.—27th. Peckeloh.—30th.

- Volpeglino; London. — 31st. Greenwich; Lichtenberg.
1872. Feb. 1. Florence.—2nd. Modena; Weybridge.—3rd. Algiers; Brighton, Sidmouth.—4th. Bombay; Lahore; Suez, Syena, Cairo, Alexandria; Athens; Constantinople; Malta; Palermo, Otranto, Rome, Florence, Genoa, Moncalieri, Aosta, &c., in general all Italy; Mostar, Lesina, Pola, Trieste; Lisbon; Madrid, Barcelona; Marseilles; Montpellier, Toulouse, Bordeaux, Lyons, Mâcon, Poitiers, Tours, Brest, Paris, Nancy, &c., Greenwich, Scilly, Stonyhurst, Dublin, whole of England; Louvain, Cleves, Cologne, Aix-la-Chapelle, Bonn; Geneva, Zurich and all Switzerland; Kremsmunster, Czernowitz, Salzbouurg, Hermannstadt, Lemberg, Cracow, Prague; Saxony; Munster; Peckeloh; Rossel, Wollgast; Breslau; Danzig; Nakschow; Bandholm on Laaland, &c.: all Europe from Turkey and Sicily to Scotland.—5th. Rome, Moncalieri; Brighton; Zurich; Freiberg.—6th. Moncalieri; Brighton; Hinterhermsdorf.—8th. Genoa, Aosta; Zurich; Lichtenberg.—9th. Genoa.—10th. Volpeglino.—11th. Brighton.—17th. Moncalieri; Constance.—22nd. Emden.—23rd. Culloden.—26th. Mondovi, Moncalieri; Emden.—27th. Genoa, Alexandria, Volpeglino.
- Mar. 1. Florence. — 2nd. Paris. — 4th. Moncalieri; Emden.—5th. Moncalieri, Aosta; Emden.—6th. Messina, Palermo, Modena; London; Emden; Peckeloh. — 7th. Genoa, Moncalieri; London.—8th. Moncalieri, Modena; London; Lichtenberg.—9th. Moncalieri.—10th. Modena; Emden; Lichtenberg.—11th. Modena; Lichtenberg, Stettin.—12th. Moncalieri, Genoa; Emden; Lichtenberg.—14th. Emden.—16th. Alexandria.—19th. Halifax. — 20th. Moncalieri; Norwich; Emden.—27th, 29th. Genoa, Mondovi.—30th. Mondovi; London; Lichtenberg.—31st. Cantalupo: Emden.
- April 1. Alexandria, Volpeglino; Emden.—2nd. Alexandria. — 3rd. Moncalieri; Stonyhurst;

Emden.—6th. Genoa, Moncalieri.—7th. Mondovi.—8th. Lyons.—10th. Milan, Mondovi, Moncalieri, Volpeglino; Paris, Brest; Stonyhurst.—11th. Genoa, Volpeglino; Greenwich; Emden, Peckeloh.—12th. Piacenza.—13th. Piacenza; Emden.—14th. Mondovi, Aosta; Emden.—15th. Moncalieri, Mondovi, Aosta; department of the Yonne, Sèvres; Greenwich, Stonyhurst.—17th, 22nd, 24th, 29th, 30th. Emden. There were in this month nine days of aurora in England, dates and places of observation not indicated.

1872. May 2. Westphalia.—7th. Peckeloh, Westphalia.—9th. Florence, Venice, Milan, Mondovi, Moncalieri, Aosta; Angiers; Verdingen (near Cologne).—10th. Turin.—15th. Aosta.—17th. Volpeglino. There were in this month six days of auroras in England, dates and places not given.
- June 4, 5. Paris.—6th. Sèvres.—7th. Emden.—10th. Angiers.—12th. Emden.—21st. Vienna, Cracow.—23rd. Nancy.—30th. Emden.—There were in this month three days of auroras in England, dates and places not given.
- July 1, 2. Brighton.—5th. Sèvres.—6th. Genoa, Velletri; Sèvres.—7th. Paris, Brest; Portsmouth, Bridport, Leenane (Ireland); Anvers; Mayence; Zurich; Cracow; Dingelstadt, Kiel.—8th. Madrid; Greenwich, Oxford.—19th. Angiers; Greenwich.—26th, 28th. Lichtenberg.—30th. Brighton.—31st. Angiers.
- Aug. 1. Brighton; Lichtenberg.—2nd. North Shields.—3rd. Aosta; Guernsey; Sillith; Zurich; Cracow; Stettin.—4th. Culloden; Emden; Laibach, Cracow.—5th. Angiers.—6th. Brighton; Zurich; Tiszafured (Hungary).—8th. Modena, Moncalieri, Volpeglino; Angiers; Guernsey; Helston, Taunton, Oxford, Hawarden, Llandudno, Culloden, Sillith; Lichtenberg.—9th. Geneva, Turin, Moncalieri; Volpeglino; Belfort; York; Llandudo; Emden; Lichtenberg.—10th. Allenheads; Prague.—13th. Culloden.—

- 14th. Brighton, Oxford, Llandudno, Cullo-
den, Stonyhurst; Cleves, Mayence, Darm-
stadt; Bremen, Peckeloh; Cracow; Leipzig;
Stettin, Koeslin.—15th. Rome (?).—25th.
Lisbon (?); Westphalia; Wermsdorf
(Saxony).—26th. Sèvres.—27th. Sèvres;
Lichtenberg.—28th. Florence, Genoa,
Moncalieri, Volpeglino, Aosta; York.—29th.
Brighton.
1872. Sept. 2. Paris, Sèvres; Brighton, Cockermouth; West-
phalia; Berlin.—3rd. Rome; Paris; Sèvres;
Hawarden; Llandudno; Koeslin.—4th.
Paris, Sèvres; London, Brighton.—5th.
Paris, Sèvres; Brighton, York.—6th. York.
—8th. Eccles.—9th. Hawarden, Stony-
hurst, York, Cockermouth, Silloth.—11th.
Sèvres.—14th. Emden.—17th. Oxford,
Silloth.—21st. Silloth.—27th. Sèvres.—
28th. Paris, Sèvres.—29th. Volpeglino;
York, Carlisle, North Shields.
- Oct. 1. Paris.—2nd. London, Valencia.—3rd. Silloth,
North Shields.—5th. Emden.—6th. Sèvres;
London; Brighton; Emden; Peckeloh.—
7th. Modena; Aosta; Paris; Brighton;
Peckeloh.—8th. Paris, Sèvres.—9th. Mo-
dena.—10th. Paris.—11th, 12th. Emden.
—13th. Peckeloh.—14th. Sèvres; Brest;
Guernsey; Peckeloh.—15th. Moncalieri,
Aosta; Sèvres; Peckeloh.—16th. Sèvres.
—17th. Sèvres; Oxford, Carlisle; Peckeloh.
—18th, 19th. Peckeloh.—22nd. Sèvres;
Emden.—23rd. Emden; Lichtenberg.—
24th, 25th. Lichtenberg.—26th. Paris;
Emden; Peckeloh; Lichtenberg.—27th.
Paris, Emden.—28th. Oxford.—30th.
Paris.—31st. Brighton.
- Nov. 1. Paris; Lichtenberg.—2nd. Brighton; Lichten-
berg.—4th. Lichtenberg.—5th. Emden.—
6th. London, Shields, Wick.—9th. Wick.—
11th. Carlisle, Cockermouth, Stonyhurst.
—15th. Helston.—19th. Paris; Em-
den; Peckeloh.—20th. Paris; Cambridge;
Peckeloh.—21st. Wick.—24th. Lichten-
berg.—25th. Moncalieri; Volpeglino; Paris;
Lichtenberg.—27th. Palermo, Messina,
Perugia, Moncalieri; Göttingen; Lichten-

- berg.—28th. Paris ; Emden.—29th. Danzig.
1872. Dec. 1. Oxford ; Peckeloh.—2nd. Cockermouth.—3rd. Milan, Piacenza, Turin, Moncalieri, Ivrea, Aosta ; Lichtenberg.—4th. Trebizond.—5th. Trebizond ; Lemberg.—6th. Lemberg ; Peckeloh.—9th. Greenwich, Oxford, Stonyhurst.—11th. Perugia.—14th. Moncalieri, Volpeglino, Aosta.—22nd. Munster.—23rd. Volpeglino, Aosta ; Peckeloh.—24th. Göttingen, Peckeloh ; Dallund.—25th. Göttingen.—26th. Stonyhurst ; Peckeloh ; Lichtenberg.—27th. Peckeloh, Dallund.—28th. Chiari, Turin, Moncalieri.—29th. Munster.
1873. Jan. 1. Greenwich.—3rd. Brighton, Liverpool.—5th. North Shields.—6th. Aosta.—7th. Paris ; Adriatic, lat $44^{\circ} 40' N.$ long. $11^{\circ} 35' E.$; Brighton, Eastbourne, Portsmouth, Greenwich, Lymington, Weybridge, Oxford, Royston, Stonyhurst.—10th. Carlisle.—16th. Streatley.—19th. Weybridge.—20th. Volpeglino.—23rd. Aosta.—25th. Wollgast.—27th, 30th. Perugia.
- Feb. 19. Aosta.—20th, Stonyhurst.—22nd. Volpeglino, Aosta ; Carlisle, Cockermouth.—23rd. Volpeglino ; Weybridge.—27th. Perugia, Moncalieri ; Carlisle, Bywell.—28th. Moncalieri
- Mar. 10. Greenwich.—20th. Brighton.—21st. Volpeglino.—22nd. Volpeglino, Aosta ; Oxford, Wisbech.—23rd. Perugia, Leghorn, Volpeglino, Aosta.—24th. Aosta.
- April 1. Portsmouth, Brighton, Oxford, Wisbech, Stonyhurst.—2nd. Guernsey ; Oxford.—18th. Eccles, Halifax, Hull, York, Stonyhurst, Carlisle, Cockermouth, Silloth.—19th. Oxford, Halifax, Hull, Stonyhurst.—20th. Oxford, Stonyhurst.—21st. Norwich.—22nd. Stonyhurst.—24th, 28th. Brighton.—30th. Guernsey ; Brighton.
- May 14. Genoa, Aosta.—15th. Genoa, Aosta ; Brighton.—23rd. Moncalieri, Aosta.—24th. Aosta.
- June 25. Stonyhurst.—26th. Perugia, Alexandria, Moncalieri, Bra, Volpeglino, Aosta.—27th. Perugia, Moncalieri, Bra, Volpeglino, Aosta.
- July 16. Brighton.
- Aug. 6. Oxford.—13th. Perugia, Umbria.—15th. Birr

- Castle (Ireland).—18th. Stonyhurst.—21st, 22nd, 23rd, 31st. Birr Castle.
1873. Sept. 15. Birr Castle.—20th. Carlisle, Birr Castle.—21st, 29th. Birr Castle.
- Oct. 11. Birr Castle.—12th. Sillith, Birr Castle.—13th. Hull.—15th. Halifax.—18th, 30th. Birr Castle.
- Nov. 2. Birr Castle.—12th, 18th. Hull.
- Dec. 9. Birr Castle.—17th. Piacenza, Turin, Moncalieri, Volpogino.—19th. Carlisle.—26th. Birr Castle.
1874. Jan. 6. Cockermouth.—12th. Birr Castle.—16th. Weybridge Heath, Sillith, Birr Castle.—17th. Stonyhurst, Carlisle.—18th. Carlisle.—24th. Helston.
- Feb. 4. Perugia, Florence, Leghorn, Udina, Ivrea. Mondovi; Toulouse; Portsmouth, Greenwich, Taunton, Weybridge Heath, Salisbury, Streatley, Leicester, Oxford, Wisbech, Eccles, Bywell, Whitehaven, Cambridge, Sunderland, Stonyhurst, Cockermouth, Allenhead, Sillith, Birr Castle; Vienna, Prague; Wollgast.—5th. Sillith, Birr Castle.—8th. Modena.—16th. Weybridge Heath.—17th. Sillith.—18th, 19th. Modena.
- Mar. 7. Parc Saint-Maur near Paris (?); Bywell, North Shields, Sillith, Birr Castle.—9th, 18th. Birr Castle.
- April 7, 9, 14. Birr Castle.
- May 8. Birr Castle.
- June 8. Oxford, Liverpool.—13th. Guernsey.
- July 2. Halifax.—22nd. Streatley.
- Aug. 31. Sillith.
- Oct. 8. England.—4th. Greenwich, England.—18th, 14th, 18th. England.—22nd. Moncalieri, Pignerol, Volpogino.—29th. Parc Saint-Maur.
- Dec. 7. Ivrea, Volpogino.
1875. Feb. 23. Nedanocz (Hungary).
- Mar. 4. Cardington.
- April 26. Brighton.—30th. Streatley.
- June 2. Volpogino.
- July 14. Stonyhurst.—24th. Sillith.—29th. Cardington.
- Sept. 20. Salisbury.
- Oct. 2. Weybridge Heath, Sillith.
- Nov. 5, 6. Cardington.—11th. Volpogino.

1875. Dec. 8. North Shields.—13th. Volpeglino.—21st. Weybridge Heath.
1876. Feb. 19. Liverpool, Whitehaven, Calcethorpe, Stonyhurst, North Shields.
- Mar. 13. Perugia, Arona.—21st. Perugia.
- April Four days of auroras in England, dates not given.
- June Two days of auroras in England, dates not given.
- Dec. 5. Weybridge.
1877. Jan. 23. Guernsey.
- Nov. 10, 28. Torquay.
1878. Mar. 25. Carlisle.
- April 3. Torquay.
- June 1. Brussels.—3rd. Breslau.
1879. No aurora in Europe this year below lat. 55° .
1880. Mar. 17. Grypskerk.
- April 8, 14. North Shields.
- Aug. 10. Shap (Westmoreland).—11th. Stonyhurst.—12th. Brighton, Strathfield, Oxford, Leicester, Bolton, Whitby, Stonyhurst, Carlisle, Silloth, North Shields.—13th. Torquay.
- Nov. 3. Greenwich, Lowestoft, Cambridge, Liverpool, Cirencester, Bootham, Downport, Dublin; Wilhelmshafen.—27th. Bradford.
1881. Jan. 31. Parma, Alexandria, Moncalieri, Volpeglino; all England; Brussels, Maldegheem, Messines, Louvain, Croix; Utrecht; Wilhelmshafen, Buxtehude (near Hamburg), all the north-east of Germany; Hohenpeissenberg, Lomtrach, Memmingen, Meersburg, Isny.
- Feb. 1. Atlantic, lat. 48° N.- 16° W.—27th. Atlantic, lat. 49° N.- 25° W.—Several auroras in England from the 7th to the 10th, exact dates and places unknown.
- Mar. 19, 20. Silloth.
- April 20. Cambridge, Llandudno, Stonyhurst; Atlantic, lat. 41° N.- 67° W.
- Sept. 12. Atlantic, lat. 50° N.- 32° W. and lat. 48° N.- 52° W.—13th. Alexandria; England; Atlantic, lat. 42° N.- 37° W.—14th. Atlantic, lat. 45° N.- 46° W.
- Oct. 16. Atlantic, lat. 42° N.- 65° W., 44° N.- 56° W., and 47° N.- 52° W.—21st, 22nd. Carlisle.
- Nov. 23. Cardington.

1881. Dec. 23. Atlantic, lat. 50° N. in the whole space between 20° and 40° W. long.
1882. Jan. 19. Atlantic, lat. 41° N.- 72° W. and 48° N.- 34° W.
- Feb. 6. Atlantic, lat. 48° N.- 51° W.—15th. Atlantic, lat. 35° N.- 15° W.—16th, 17th. Bermerside.—20th. Bedford, Bermerside.
- Mar. 19. Atlantic, lat. 41° N.- 59° W.—21st. Stonyhurst,
- April 13, 14, 15. Middle of the Atlantic between 41° and 48° N. and 25° and 70° W.—16th. Hanover; middle of the Atlantic.—18th, 19th, 20th, 21st. Middle of the Atlantic.
- May 11. Atlantic, lat. 41° N.- 62° W. — 14th. Méru Ternat (Haute-Marne), Pornic; Worcester, Oldham, Dublin; Atlantic, lat. 41° N.- 27° W. and 47° N.- 17° W. — 29th. Atlantic, lat. 41° N.- 66° W.
- July 16. Atlantic, from 40° to 42° N. and from 64° to 67° W.
- Aug. 4. Atlantic, from 37° to 47° N. and from 38° to 75° W.—5th. Stonyhurst.—9th. Atlantic, lat. 42° N.- 65° W.—11th. Atlantic, lat. 40° N.- 65° W. and lat. 43° N.- 49° W. — 14th. Atlantic, lat. 41° N.- 61° W.—22nd. Atlantic, lat. 41° N.- 57° W.—23rd. Stonyhurst.—30th. Worcester.
- Sept. 4. Atlantic, lat. 48° N.- 60° W.—5th. Atlantic, lat. 45° N.- 48° W.—11th. Atlantic, lat. 41° N.- 62° W.—12th. Atlantic, lat. 42° N.- 54° W. and lat. 49° N.- 12° W.—20th. Atlantic, lat. 58° N.- 18° W.
- Oct. 1. Halifax.—2nd. Mondragona, Florence, Moncalieri; Paris, parc Saint-Maur, Saint-Leu, Taverny, Evreux, La Teste, Nantes, Dinard, Cherbourg, Landelles, Séez, Laon, Amiens, Lille; Guernsey; Torquay, Greenwich, Oxford, Leicester, Hull, Scarborough, Cheltenham, Newcastle-on-Tyne, Dublin, &c.; Brussels, Louvain, Utrecht; Basle, Trogen; Praganza; Pola, Budapest, Breslau, Grünberg, Swinemunde; all the Atlantic.—3rd. Oxford, Hull.—4th. All the Atlantic.—5th. Stonyhurst, Silloth; Atlantic.—8th, 15th, 16th, 17th. Atlantic.—18th. Croydon.—22nd, 24th, 28th, 29th. Atlantic.—30th. Stonyhurst.
- Nov. 1. Oxford.—11th. Atlantic.—12th. Stonyhurst,

- York, Silloth; Atlantic.—13th. Stonyhurst, Bolton, York; Atlantic.—14th. Stonyhurst, York; Atlantic.—15th, 16th. York.—17th. Rome, Florence, Moncalieri, Volpogino; Nice, Marseilles, Grenoble, Valencia, Montpellier, Paris, Laon, Cherbourg, Saint-Brieuc, Ploërmel, Douai, &c.; Guernsey; Torquay, Greenwich, Osborne, Oxford, Hull, Halifax, Stonyhurst, York, Silloth, &c.; Brussels, Bruges, Tournai, Antwerp, all Belgium; Utrecht, Zieriksee, all Holland; all Switzerland; Fiume, Pola, Lussinpiccolo, Agram, Roveredo, Boëhm, Aicha; Atlantic.—18th. Torquay, Cardington; Atlantic.—19th, 20th. Oxford; Atlantic.—25th. Atlantic.
1882. Dec. 12. Atlantic.—15th. Atlantic, between 30° and 59° W.—19th. Oxford, York.—23rd. Halifax.
1883. Jan. 24. Geestemunde.
- Feb. 1. All the Atlantic.—2nd. West of the Atlantic.—12th. Hull.—15th. Brixham (?).—24th. Cambridge.
- Mar. 3. Oxford.—4th, 8th. Atlantic.—10th. Oxford.—28th. Atlantic.
- April 2. Whitchurch.—5rd, 24th. Stonyhurst; Atlantic.
- May 11, 14. Stonyhurst.—26th. Whitchurch.
- June 30. Atlantic.
- July 1, 6, 29, 30. Atlantic.
- Aug. 6. Whitchurch.—7th, 22nd. Atlantic.—30th. Stonyhurst.
- Sept. 4. Atlantic.—5th. Silloth; Atlantic.—7th. Atlantic.—8th. Stonyhurst.—11th, 12th, 15th, 16th, 23rd, 24th, 25th. Atlantic.
- Oct. 4. Stonyhurst; Atlantic.—5th. Cambridge, Stonyhurst, Carlisle, Silloth; Atlantic.—16th, 31st. Atlantic.
- Nov. 1. Atlantic from 30° to 75° W.—2nd. Atlantic, from 13° to 55° W.—5th. Atlantic, lat. 46° N.—49° W.—8th. Beachy Head.—16th. Atlantic, lat. 37° N.—76° W.—21st. Atlantic, from 43° to 75° W.—22nd. Llandudno, Silloth; Atlantic, from 58° to 68° W.—28th. Blackheath.—30th. Atlantic, from 31° to 39° W., and in the south as far as lat. 39° N.
- Dec. 1. Torquay.—2nd. Torquay, Whitchurch.
1884. Jan. 17. Carlisle.—18th. Atlantic, lat. 46° N.—46° W.—19th. Carlisle.

1884. Feb. 24. Stonyhurst.
 — Mar. 21. Stonyhurst.
 — April 2. Stonyhurst.—14th. Atlantic, from 42° to 67° W.
 —17th. Atlantic, from 41° N.-65° W.—24th.
 Oxford, Cambridge, Halifax, Stonyhurst;
 Atlantic, lat. 46° N.-39° W., and lat. 48° N.-
 34° W.—30th. Atlantic, lat. 41° N.-70° W.
 — June 18. Atlantic, lat. 45° N.-44° W.—22nd. Atlantic,
 lat. 41° N.-66° W., and lat. 41° N.-71° W.
 — Aug. 20. Atlantic, lat. 50° N.-22° W.—31st. Atlantic,
 lat. 44° N.-59° W.
 — Sept. 13. Atlantic, lat. 49° N.-29° W.—14th. Atlantic, lat.
 41° N.-67° W.—17th, 18th. Stonyhurst.
 — Oct. 1. North Sea; Atlantic, lat. 45° N.-55° W.—3rd,
 4th. Stonyhurst.—6th. Atlantic, lat. 46° N.-
 50° W.—15th. Atlantic, lat. 47° N.-42° W.
 —16th. Stonyhurst.
 — Nov. 2. Atlantic, lat. 48° N.-36° W.
 — Dec. 14. Atlantic, lat. 41° N.-67° W.
 1835. Jan. 22. Atlantic, lat. 50° N.-27° W.
 — Feb. 5. Stonyhurst; Atlantic, lat. 49° N.-37° W.—11th.
 Atlantic, lat. 44° N.-59° W.
 — Mar. 6, 14. Stonyhurst.—15th. Torquay, Brighton,
 Greenwich, Leicester, Halifax, Cirencester,
 Walton-on-the-Naze; all the Atlantic from
 the Channel to 47° W.
 — May 7. Atlantic, lat. 46° N.-36° W.—10th. Amster-
 dam.—12th. Atlantic, lat. 46° N.-22° W.—
 13th. Dublin; Atlantic, lat. 43° N.-46° W.,
 lat. 46° N.-20° W. and lat. 48° N.-15° W.—
 14th. Stonyhurst.
 — June 12. Amsterdam,
 — July 1. Leicester.—9th. Atlantic, lat. 50° N.-22° W.—
 11th. Atlantic, lat. 49° N.-40° W.—21st.
 Leicester, Carlisle.—22nd. Carlisle.—27th.
 Leicester.
 — Aug. 13. Stonyhurst.—28th. Atlantic, lat. 50° N.-32°
 W.
 — Sept. 2. Atlantic, lat. 47° N.-51° W.—3rd. Atlantic,
 lat. 45° N.-55° W.—4th. Atlantic, lat. 40°
 N.-70° W.—5th. Atlantic, lat. 39° N.-70° W.
 —11th. Stonyhurst.—14th. Atlantic, lat.
 44° N.-60° W.—15th. Atlantic, lat. 49° N.-
 37° W.
 — Oct. 8. Atlantic, lat. 47° N.-42° W.—12th. Atlantic,
 lat. 47° N.-47° W.—14th. Atlantic, lat. 48°

- N.-42° W.—15th. Atlantic, lat. 47° N.-4° W. and lat. 51° N.-22° W.
1885. Nov. 7. Atlantic, lat. 44° N.-52° W. and lat. 49° N.-21° W.—9th. Atlantic, lat. 44° N.-55° W. and lat. 47° N.-45° W.—10th. Atlantic, lat. 48° N.-37° W.
1886. Jan. 9. Torquay.—21st, 29th. Königsberg.
 — Feb. 20, 21. Königsberg.
 — Mar. 3, 14. Königsberg.—30th. Yébleron, Rolleville (Seine-Inf.), la Mothe-Achard (Vendée), west of France; Dublin, Ramelton, Kingstown; Magdeburg, Greifswald, Greifenberg, Königsberg.
 — Apr. 11. Liverpool; Königsberg.
 — July 12. Dax.—27th. Torquay, Paisley, Gillsland, Ramelton (Ireland); Königsberg.—30th. Königsberg.
 — Nov. 2. Königsberg.
 Dec. 25. Königsberg.
1887. Feb. 12. Bothkamp.—14th. Königsberg.
 — Mar. 15. Stonyhurst.—20th. Königsberg.
 — Apr. 21. Königsberg.
 — May 17. Königsberg.—25th. Atlantic, lat. 47° N.-33° W.
 — June 18. Atlantic, lat. 49° N.-15° W.—19th. Atlantic, lat. 41° N.-69° W.—24th. Königsberg.
 — Aug. 29. Atlantic, lat. 47° N.-38° W.
 — Oct. 27, 31. Königsberg.
 — Nov. 21. Atlantic, lat. 46° N.-52° W. and lat. 45° N.-48° W.
 — Dec. 6. Atlantic, lat. 44° N.-57° W.—16th. Atlantic, lat. 50° N.-21° W., and lat. 46° N.-48° W.
1888. Jan. 13. Königsberg.
 — Mar. 8. Atlantic, lat. 44° N.-55° W., and lat. 54° N.-27° W.—15th. Atlantic, lat. 46° N.-38° W. and lat. 42° N.-56° W.—29th. Königsberg.
 — Apr. 2. Königsberg; Atlantic, lat. 55° N.-27° W.—8th. Königsberg.—11th. Atlantic, lat. 46° N.-42° W., and lat. 48° N.-31° W.
 — May 6. Rock-Ferry (near Liverpool).—7th. Atlantic, lat. 40° N.-72° W.—11th. Atlantic, lat. 46° N.-42° W.—20th. Atlantic, lat. 44° N.-52° W.—28th. Königsberg.
 — July 7. Atlantic, lat. 47° N.-33° W.
 — Aug. 3. Atlantic, lat. 47° N.-44° W.
 — Sept. 7. Atlantic, lat. 42° N.-67° W., and lat. 44° N.-55° W.—9th. Atlantic, lat. 42° N.-64° W.—

- 26th. Atlantic, lat. 50° N.- 32° W.—28th. Atlantic, lat. 58° N.- 9° W.
1888. Oct. 2. Atlantic, lat. 54° N.- 84° W.—5th. Atlantic, lat. 41° N.- 70° W., and lat. 46° N.- 48° W.—8th. Atlantic, lat. 53° N.- 37° W., and lat. 53° N.- 43° W.—10th. Atlantic, lat. 48° N.- 40° W.—11th. Atlantic, lat. 50° N.- 32° W.—19th. Atlantic, lat. 45° N.- 57° W.—26th. Königsberg.—30th. Atlantic, lat. 52° N.- 55° W.—31st. Atlantic, lat. 51° N.- 27° W.
- Nov. 1. Atlantic, lat. 49° N.- 86° W.—4th. Königsberg; Atlantic, lat. 50° N.- 25° W.—6th. Atlantic, lat. 44° N.- 55° W.—9th. Atlantic, lat. 50° N.- 19° W.—26th. Atlantic, lat. 48° N.- 42° W.
1889. Feb. 19. Atlantic, lat. 45° N.- 48° W.
- Mar. 5. Atlantic, lat. 43° N.- 57° W.
- April 8. Atlantic, lat. 46° N.- 40° W.—25th. Atlantic, lat. 47° N.- 44° W., and lat. 48° N.- 46° W.
- Sept. 15. Atlantic, lat. 46° N.- 51° W.
- Oct. 19. Atlantic, lat. 43° N.- 65° W.
- Nov. 1. Atlantic, lat. 44° N.- 56° W.—26th. Halifax; Atlantic, lat. 47° N.- 46° W., and lat. 56° N.- 25° W.
- Dec. 27. Atlantic, 500 miles to the east of Cape Race.
1890. Jan. 27. Halifax.
- July 16. Atlantic, lat. 52° N.- 58° W.—23rd. Atlantic, lat. 50° N.- 46° W.—28th. Atlantic, lat. 52° N.- 56° W.
- Aug. 14. Atlantic, lat. 40° N.- 73° W.—15th. Atlantic, lat. 49° N.- 39° W.—16th. Atlantic, lat. 48° N.- 45° W.—18th. Atlantic, lat. 45° N.- 55° W.
- Sept. 3. Atlantic, lat. 44° N.- 59° W.—10th. Atlantic, lat. 46° N.- 53° W., and lat. 46° N.- 55° W.—11th. Atlantic, lat. 49° N.- 37° W., lat. 52° N.- 56° W., lat. 45° N.- 59° W., lat. 44° N.- 63° W. and lat. 40° N.- 67° W.—12th. Atlantic, lat. 50° N.- 21° W., lat. 50° N.- 30° W. and lat. 53° N.- 51° W.—13th. Atlantic, lat. 55° N.- 45° W.—15th. Atlantic, lat. 50° N.- 39° W. and lat. 46° N.- 42° W.—19th. Atlantic, lat. 43° N.- 62° W.
- Oct. 5. Atlantic, lat. 49° N.- 36° W., lat. 49° N.- 38° W., lat. 45° N.- 54° W., and lat. 40° N.- 69° W.—11th. Atlantic, lat. 44° N.- 60° W.—14th. Atlantic, lat. 51° N.- 30° W.—17th. Atlantic,

- lat. 44° N.- 50° W. — 18th. Atlantic, lat. 49° N.- 19° W.
1890. Nov. 7. Atlantic, lat. 42° N.- 67° W. and lat. 40° N.- 70° W.—8th. Atlantic, lat. 44° N.- 60° W.—
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THE END.

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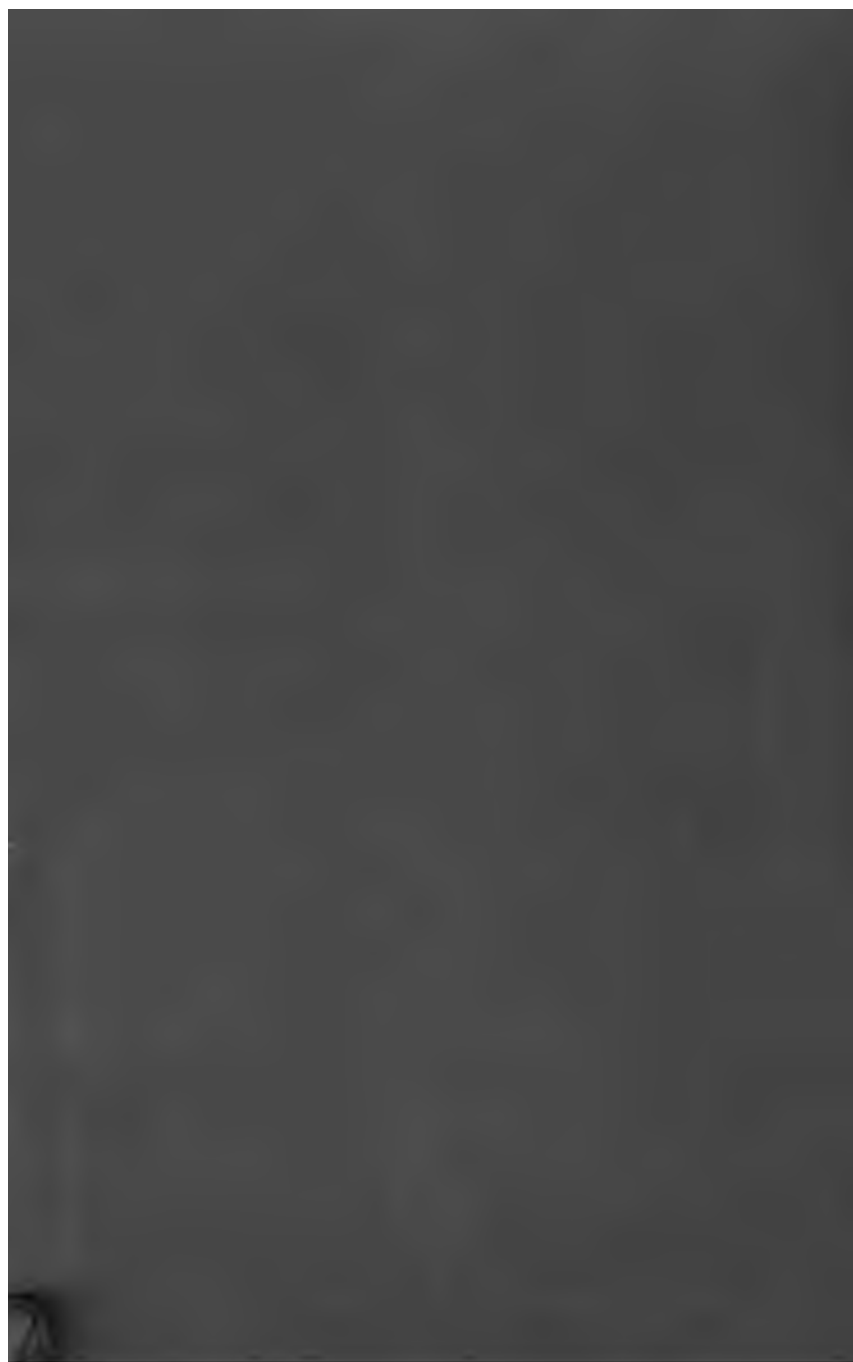
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